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(71) Applicant: AMGEN INC. [US/US]; Amgen Center, 1840 Dehavilland Drive, Thousand Oaks, CA 91320-1789 (US).	(72) Inventors: BARTLEY, Timothy, D.; 2431 McCrea Road, Thousand Oaks, CA 91362 (US). BOYLE, William, J.; 13024 Williams Ranch Road, Moorpark, Ca 93021 (US). FOX, Gary, M.; 35 West Kelly Road, Newbury Park, CA 91320 (US). WELCHER, Andrew, A.; 1431 Merriman Drive, Glendale, CA 91202 (US). MAGAL, Ella; 3022 Windrift Court, Thousand Oaks, CA 91360 (US). LINDBERG, Richard, A.; 269 Yellowstone Avenue, Thousand Oaks, CA 91360 (US).	(83) Date of publication of the international search report: 29 May 1997 (29.05.97)	
(74) Agents: ODRE, Steven, M. et al.; Amgen Inc., Amgen Center, 1840 Dehavilland Drive, Thousand Oaks, CA 91320-1789 (US).			
(54) Title: ECK RECEPTOR LIGANDS			
(57) Abstract			
Ligands which bind to the <i>eck</i> receptor are disclosed. More particularly, polypeptides which bind specifically to the <i>eck</i> receptor (<i>eck</i> receptor binding proteins or EBPs) and DNA sequences encoding said polypeptides are disclosed. Methods of treatment using <i>eck</i> receptor ligands and soluble <i>eck</i> receptor are disclosed, as are pharmaceutical compositions containing same. A rapid and sensitive method for the detection of receptor binding activity in crude samples is provided.			

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INTERNATIONAL SEARCH REPORT

International Application No
PCT/US 96/07170A. CLASSIFICATION OF SUBJECT MATTER
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According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 C12N C07K G01N A61K

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	EP 0 597 503 A (AMGEN INC) 18 May 1994 see the whole document ---	1-40,44, 45
X	WO 91 17427 A (NEDERLANDSE ORGANISATIE VOR TOEGEPAST-NATUURWETENSCHAPELIJK ONDERZOEK) 14 November 1991 see page 1, line 5 - line 19; table A ---	21
Y	NATURE, vol. 368, no. 6471, 7 April 1994, LONDON GB, pages 558-560, XP002013446 TIMOTHY D. BARTLEY ET AL.: "B61 is a ligand for the ECK receptor protein-tyrosine kinase" see the whole document ---	1-3, 8-16,19, 20, 23-25, 27-30, 32,33,44
		-/-

 Further documents are listed in the continuation of box C. Patent family members are listed in annex.

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1 Date of the actual completion of the international search 16 April 1997	Date of mailing of the international search report 22.04.97
Name and mailing address of the ISA European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+ 31-70) 340-2040, Tx. 31 651 epo nl, Fax. (+ 31-70) 340-3016	Authorized officer Montero Lopez, B

INTERNATIONAL SEARCH REPORT

International Application No
PCT/US 96/07170

C(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	WO 92 07094 A (THE REGENTS OF THE UNIVERSITY OF MICHIGAN) 30 April 1992 cited in the application see page 2, line 12 - page 3, line 3 see page 9, line 30 - page 10, line 10 see page 15, line 26 - page 16, line 2 ---	1,8-16, 32,33,44
Y	J. BIOL. CHEM. (1995), 270(10), 5636-41 CODEN: JBCHA3;ISSN: 0021-9258, 1995, XP002013447 SHAO, HAINING ET AL: "Characterization of B61, the ligand for the Eck receptor protein-tyrosine kinase" see abstract see page 5629, left-hand column, paragraph 4 - page 5641, left-hand column, paragraph 2 ---	1-3, 8-14,16, 19,20, 23-25, 27-30,44
Y	SCIENCE (WASHINGTON D C) 268 (5210). 1995. 567-569. ISSN: 0036-8075, XP002013448 PANDEY A ET AL: "Role of B61, the Ligand for the Eck Receptor Tyrosine Kinase, in TNF-alpha-Induced Angiogenesis." see abstract ---	32,33
P,X	ONCOGENE (1995), 11(5), 879-83 CODEN: ONCNES;ISSN: 0950-9232, 1995, XP000601390 TAKAHASHI, HIROSHI ET AL: "Molecular cloning and expression of rat and mouse B61 gene: implications on organogenesis" see the whole document ---	1,3,4, 8-16,19, 20
P,X	J. NEUROSCI. RES. (1996), 43(6), 735-44 CODEN: JNREDK;ISSN: 0360-4012, 1996, XP000601387 MAGAL, E. ET AL: "B61, a ligand for the Eck receptor protein-tyrosine kinase, exhibits neurotrophic activity in cultures of rat spinal cord neurons" see abstract see page 738, left-hand column, paragraph 2 - page 743, left-hand column, paragraph 2 ---	23-25, 41-45
P,X	WO 95 27060 A (REGENERON PHARMA) 12 October 1995 see page 1, line 22 - line 26 see page 6, line 10 - line 15 see page 8, line 14 - page 9, line 15 see page 13, line 4 - page 20, line 12 see page 31, line 14 - page 32, line 12 -----	1,2, 8-16,19, 23-25
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INTERNATIONAL SEARCH REPORT

International application No.

PCT/US 96/07170

Box I Observations where certain claims were found unsearchable (Continuation of item 1 of first sheet)

This International Search Report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. Claims Nos.: because they relate to subject matter not required to be searched by this Authority, namely:
Remark: Although claims 23-25, 27-35, 41-43, and, partially, as far as concerning an in-vivo method, claims 36-40, are directed to a method of treatment of the human/animal body, the search has been carried out and based on the alleged effects of the compounds.
2. Claims Nos.: because they relate to parts of the International Application that do not comply with the prescribed requirements to such an extent that no meaningful International Search can be carried out, specifically:
3. Claims Nos.: because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box II Observations where unity of invention is lacking (Continuation of item 2 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

1. As all required additional search fees were timely paid by the applicant, this International Search Report covers all searchable claims.
2. As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.
3. As only some of the required additional search fees were timely paid by the applicant, this International Search Report covers only those claims for which fees were paid, specifically claims Nos.:
4. No required additional search fees were timely paid by the applicant. Consequently, this International Search Report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

The additional search fees were accompanied by the applicant's protest.

No protest accompanied the payment of additional search fees.

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No

PCT/US 96/07170

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ECK RECEPTOR LIGANDS

The invention relates generally to ligands of the eck receptor and, in particular, to polypeptide ligands termed eck receptor binding proteins (EBPs). Also encompassed by the invention are methods of treatment using eck receptor ligands and soluble eck receptor, and pharmaceutical compositions containing same. A rapid and sensitive method for the detection of receptor binding activity in crude samples is described.

Background of the Invention

Peptide growth and differentiation factors elicit responses in target cells by means of specific interactions with receptors at the cell surface. Growth factor receptors are typically membrane glycoproteins with distinct extracellular, transmembrane, and intracellular domains. The structural segregation of the domains corresponds to function (Ullrich et al. *Cell* 61, 203 (1990)); the extracellular domain appears to be responsible for ligand binding and ligand-mediated receptor dimerization (Cunningham et al. *Science* 254, 821 (1991); Lev et al. *J. Biol. Chem.* 267, 10866 (1992)), while the intracellular domain of the receptor, or the intracellular domain of an accessory element (Takeshita et al. *Science* 257, 379 (1992)), is responsible for signal transduction. Much of the specificity of growth factor activity is dictated by the interaction with the binding site on the extracellular domain of the cognate receptor. Chimeric receptors, engineered to contain the extracellular domain of one receptor and the intracellular domain of a second receptor, retain the ligand specificity of the extracellular component (Lehvaslaiho et al. *EMBO J.* 8, 159 (1989)). The downstream signaling pathways

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activated by such chimeric receptors correspond to those activated by the intracellular component. In many cases soluble forms of receptors, consisting of only the extracellular domains, retain ligand binding activity

5 (Lev et al. *ibid*; Duan et al. *J. Biol. Chem.* **266**, 413 (1991)). Truncated receptors have been identified in serum (Fernandez-Botran *FASEB J.* **5**, 2567 (1991)), cell culture supernatants (Zabrecky et al. *J. Biol. Chem.* **266**, 1716 (1991)), and have been produced through

10 recombinant techniques (Lev et al. *ibid*, Duan et al. *ibid*).

Recent progress in nucleic acid sequencing and amplification technologies has resulted in the identification of an increasing number of genes which

15 code for previously unidentified growth factor receptors (Wilks *Proc. Natl. Acad. Sci. USA* **36**, 1603 (1989); Lai et al. *Neuron* **6**, 691 (1991)). As a result, there is a demand to develop procedures which can define the biological roles of orphan receptors, including

20 techniques which can identify ligands for these receptors (McConnell et al. *Science* **257**, 1906 (1992))

Receptor affinity technology is one approach to this problem. This technology may augment existing strategies for the isolation of novel growth factors,

25 since it allows the detection of ligands when biological responses are subtle or undefined.

Recent reports have suggested that the extracellular domains of receptors can be exploited as growth factor-specific affinity reagents. Bailon et al.

30 (*Biotechnology* **5**, 1195 (1987)) have shown that the extracellular domain of the IL-2 receptor α subunit can be immobilized on chromatographic media and used for the purification of recombinant IL-2. A genetic fusion of the *kit* extracellular domain with an alkaline

35 phosphatase enzymatic tag allowed the identification of a cell associated ligand for the receptor (Flanagan

et al. *Cell* **63**, 185 (1990)). Lupu et al. (*Proc. Natl. Acad. Sci. USA* **89**, 2287 (1992)) have reported the affinity purification of an activity which binds to the immobilized extracellular domain of the *erbB-2* gene product.

The *eck* gene, originally identified by cDNA cloning from a human epithelial cell library, encodes a 130 kDa receptor-like protein-tyrosine kinase (*p130eck*) (Lindberg et al. *Mol. Cell. Biol.* **10**, 6316 (1990)).

10 Immunohistochemical and mRNA screening of tissues and cell lines suggest that *eck* expression is highest in cells of epithelial origin. By analogy with genes encoding other receptor-like protein-tyrosine kinases, *eck* may be a proto-oncogene and therefore may have a
15 role in carcinogenesis. This potential role for *eck* is more likely given the frequent involvement of epithelial cells in human cancers. Receptor protein kinases are typically activated through interaction with one or more ligands. However, a ligand capable of activating
20 *p130eck* has not yet been reported. The identification of such a ligand may be important in defining the role of *p130eck* activation in the development of some human cancers.

It is therefore an object of this invention to
25 identify one or more ligands for *p130eck*. The possible role of *p130eck* in the transformation of epithelial cells to a cancerous state suggests that identification of the ligand responsible for receptor activation may have therapeutic implications for some epithelial cell-derived malignancies.

SUMMARY OF THE INVENTION

The present invention generally relates to eck receptor ligands. More particularly, polypeptides which bind specifically to the eck receptor, herein referred to as eck receptor binding proteins (EBPs), are disclosed. EBPs were identified and isolated by affinity chromatography using immobilized extracellular eck receptor. EBPs of the present invention may also induce phosphorylation of the receptor upon binding which may trigger changes in target cell physiology, e.g. cell growth and/or differentiation. EBP has an amino acid sequence substantially as shown in SEQ. ID. NO. 1. In a preferred embodiment, EBP has a portion of the amino acid sequence as shown in SEQ. ID. NO. 1. For example, EBP has an amino acid sequence terminating at position 150.

A polypeptide specifically binding the eck receptor, wherein the polypeptide has substantially the same amino acid sequence as shown in SEQ. ID. NO. 1 and has a methionine residue at position -1 is also included. By way of example, the polypeptide is [Met⁻¹] EBP¹⁻¹⁵⁰ or [Met⁻¹] EBP¹⁻¹⁵⁹. Also provided for are DNA sequences encoding same. EBPs may also be analogs which have a portion of the amino acid sequence as shown in SEQ. I.D. NO. 1. Examples of such analogs are EBPs terminating at positions 167, 171 or 180.

The invention also provides for EBP as a product of procaryotic or eucaryotic expression of an exogenous DNA sequence, i.e., eck receptor binding protein is derived from recombinant DNA methods.

A method for detecting receptor binding activity in crude samples by monitoring the binding to an immobilized ligand binding domain of a receptor is also encompassed by the invention.

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Pharmaceutical compositions comprising a therapeutically effective amount of an eck receptor ligand are described. Also included is the use of an eck receptor ligand in the treatment of certain types of 5 cancers, particularly those characterized by epithelial cell proliferation. eck receptor ligands may also be used for the treatment of wounds to promote healing, for increasing hematopoiesis, for stimulating the proliferation of hepatocytes and colon crypt cells, and 10 for treating neurological disorders.

The use of therapeutically effective amounts of ligand antagonists or soluble eck receptor for modulating the biological effects of eck receptor ligands is also encompassed by the invention. Such 15 treatments are useful in cancer therapy and in the control of inflammation.

BRIEF DESCRIPTION OF THE FIGURES

20 Figure 1A. SDS-PAGE analysis of immobilized eck-x affinity chromatography. Conditioned medium from HCT-8 cells was concentrated, diafiltered, and loaded onto a 1 ml column of immobilized eck-x (1 mg eck-x per ml of gel). Samples were concentrated in the presence 25 of 0.02% SDS when necessary; equivalent original volumes are shown in parentheses. Lane 1, Column load (20 ml). Lane 2, Unbound fraction (20 ml). Lane 3, PBS wash (50 ml). Lane 4, pH 4.0 elution, fraction 1 (200 ml). Lane 5, pH 4.0 elution, fraction 2 (200 ml). Lane 6, 30 pH 4.0 elution, fraction 3 (200 ml).

Figure 1B. SDS-PAGE analysis of immobilized eck-x affinity chromatography. Cell supernatants from CHO cells transfected with EBP gene were treated and 35 analyzed as described in legend to Figure 1A.

- 6 -

Figure 2. Gel Filtration analysis of purified EBP from HCT-8 cell line. EBP, purified by immobilized eck-x receptor affinity chromatography, was amended with 50 µg/ml BSA and injected onto a Superdex 75 column.

5 Fractions were tested for eck-x binding activity by BIACore.

Figure 3. Q-Sepharose chromatography of EBP from CHO cells transfected with EBP cDNA. Samples were 10 analyzed by SDS-PAGE and probed with anti-EBP antibody.

Figure 4. Analysis of release of membrane-bound EBP from CHO cell surfaces by phospholipase C treatment. "-" indicates incubation in the absence of 15 phospholipase C; "+" indicates incubation in the presence of phospholipase C. Time of incubation was 0, 5 and 10 minutes.

Figure 5. Chemical crosslinking of ^{125}I -rEBP 20 to CHO 19.32 cells expressing eck. Cells were treated as described in Example 5. Lane 1, ^{125}I -rEBP + CHO 19.32 Lane 2, ^{125}I -rEBP + CHOd- (untransfected). Lane 3, ^{125}I -rEBP + CHO 19.32, no crosslinker added. Lane 4, ^{125}I -rEBP + CHO 19.32 + 50X unlabelled rEBP.

25

Figure 6. Activation of the eck receptor tyrosine kinase in LIM 2405 cells treated with purified rEBP. Serum-starved LIM 2405 cells were treated for 10-30 min at 37°C with increasing concentration of purified rEBP (CHOd-/EBP). The treated cells were lysed and then immunoprecipitated with anti-eck C-terminal antibody. The immunoprecipitates were split into two equal samples and resolved in parallel in a 7.5% SDS polyacrylamide gel. The gel was blotted onto membrane, then probed 35 with either monoclonal anti-phosphotyrosine antibody (upper panel) or anti-eck C-terminus (lower panel).

Migration of the eck polypeptide is marked by an arrowhead.

Figure 7. Binding of CHO-derived EBP in 5 various detergent formulations to immobilized eck receptor as measured by BIAcore. Purified EBP was diluted to 100 μ g/ml in PBS in the presence or absence of detergent and incubated for 2 hrs. at 3°C. Protein samples were diluted to the concentrations indicated in 10 the figure and tested for eck receptor binding.

Figure 8. CFU-C and CFU-Mk formation in bone marrow cultures in the presence of EBP alone and in combination with IL-3, erythropoietin or GM-CSF.

15

Figure 9. Incorporation of 3 H-thymidine in hepatocyte cultures in the presence of EBP, acidic FGF or KGF.

20

Figure 10. EBP promotes neuronal survival in cultured spinal cord neurons. Concentration-dependence of EBP effect on the number of spinal cord neurons in 9-day old cultures is shown, expressed as percent of control level at that time. Each value is mean \pm 25 standard deviation of 3-4 independent cultures. Differences between controls and treated cultures are highly significant ($P<0.005$; t test).

30

Figure 11. EBP promotes neurite outgrowth in cultured spinal cord neurons. Phase contrast micrographs of MAP2-immunostained 6 day old cultures.

35

(a) untreated culture; (b) and (c), untreated representative motoneurons (identified morphologically as large neurons with stellate soma and several thick and long processes); (d) culture treated for six days with 500 ng/ml EBP; (e) and (f), representative

motoneurons treated for the six days with 500 ng/ml EBP. All photographs are at the same magnification. Scale bar in (c) is 50 μ m.

5 Figure 12. Involvement of Eck receptor in EBP-mediated motoneuron survival and neurite outgrowth.

10 (A) Number of motor neurons per well in 3-day old motor neuron enriched cultures either untreated (Control, 753 \pm 131) or treated with 250 ng/ml EBP in the absence of antibodies (EBP, 1550 \pm 413), in the presence of 15 μ g/ml of an anti-human Eck monoclonal antibody which recognizes the rat Eck extracellular domain (EBP & anti-ECK1, 595 \pm 46), in the presence of 20 μ g/ml of an anti-human Eck monoclonal antibody which does not

15 recognize rat Eck (EBP & anti-ECK2, 1532 \pm 32), or in the presence of 50 μ g/ml of anti-EBP antibody (EBP & anti-EBP, 629 \pm 35). Treatment with EBP significantly enhanced survival over control levels ($P < 0.005$; t test). Addition of anti-EBP and anti-ECK1 antibodies

20 significantly reduced the effects of EBP ($P < 0.05$; t test). Each value is the mean \pm SD of 3-7 independent cultures.

25 (B) Mean neurite lengths (μ m) in motor neuron cultures that underwent treatments similar to those shown in (A): Control (112 \pm 9); EBP (177 \pm 12); EBP & anti-ECK1 at 6 μ g/ml (85 \pm 7); EBP & anti-ECK2 at 8 μ g/ml (162 \pm 19); EBP & anti-EBP at 10 μ g/ml (111 \pm 10). Each value is the mean \pm SE of about 100 neurite length determinations. Survival data from the experiment shown

30 in (B) yielded results similar to those shown in (A).

DETAILED DESCRIPTION OF THE INVENTION

The present invention relates to ligands which bind to the eck receptor, a 130 kDa protein tyrosine kinase identified by Lindberg et al., supra. An eck

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receptor ligand may activate the receptor by inducing autophosphorylation by the protein-tyrosine kinase catalytic domain. Protein-tyrosine kinases are part of the signal transduction pathway which modulates cell

5 proliferation and differentiation. Therefore, a ligand capable of activating protein-tyrosine kinase activity of the *eck* receptor will likely be important in modulating the growth and differentiation of cells expressing the receptor. An *eck* receptor ligand may be
10 a polypeptide, peptide, or non-protein molecule which binds to and/or activates the *eck* receptor.

The present invention provides for novel polypeptides which specifically bind to the *eck* receptor. These polypeptides are referred to as *eck* 15 binding proteins, or EBPs. EBPs have been isolated from the conditioned medium of SK-BR-3 and HCT-8 cell lines by receptor affinity chromatography using the *eck* receptor extracellular domain (*eck-x*) as the affinity reagent. Construction of the *eck-x* gene and expression
20 and purification of *eck-x* are described in Example 1. The purification of *eck* binding proteins on immobilized *eck-x* is described in Example 3A.

EBP derived from the HCT-8 cell line exists in several different molecular weight forms in the range of
25 21-27 kDa as revealed by SDS-PAGE (Figure 1A). N-terminal sequencing of EBPs in the 21-27 kDa range revealed a single sequence (Example 3B). After enzymatic removal of carbohydrate chains, a mixture of species in the range of 17-19 kDa was observed,
30 suggesting that the different forms may result from alternative post-translational processing of the protein.

The N-terminal sequence of SK-BR-3 derived EBP was identical to the N-terminal amino acid sequence
35 predicted from the expression of the B61 gene (Holzman et al. *Mol Cell. Biol.* 10, 5830 (1990); PCT Application

No. WO 92/07094). The B61 gene was originally identified by differential hybridization as an immediate-early response gene and its expression was induced in cultured human vascular endothelial cells by 5 treatment with tumor necrosis factor- α . Based upon the sequence of the EBP gene, the encoded protein was predicted to have 187 amino acids in its mature form. The isolation and characterization of the EBP-encoded protein has not been previously reported. It was 10 proposed that the EBP protein functions as a cytokine-induced marker for inflammation and therefore is useful as a diagnostic reagent for the detection of an impending inflammatory response (PCT Application No. WO 92/07094).

15 cDNA encoding EBP having the N-terminal sequence determined in Example 3B was cloned and sequenced and, as expected, found to be identical to the B61 gene (Holzman et al. *supra*). The B61 DNA sequence reported by Holzman et al. is shown in SEQ. ID. NO. 11.

20 The EBP (or EBP gene) was expressed in CHO cells and in *E. coli* as described in Example 4. At least two polypeptides having different molecular weights were expressed by the EBP gene in CHO cells. C-terminal sequencing of CHO cell EBP revealed only the sequence 25 -lys-arg-leu-ala-ala-COOH which indicated a polypeptide of 150 amino acid residues. This polypeptide is referred to as EBP1-150. A polypeptide of 187 amino acids corresponding to the predicted EBP protein, if present at all, represents a very minor product of CHO 30 cell expression. Expression of the EBP gene (lacking the leader sequence) in *E. coli* resulted in a single product on SDS-PAGE having a C-terminal sequence predicted for the full-length protein. This polypeptide which has a methionine residue at the amino terminus is 35 designated [met-1] EBP1-187 and, with the exception of

the N-terminal met, is identical in amino acid sequence to the predicted EBP protein.

CHO cell-derived rEBP has been shown to interact with the *eck* receptor by the following

5 experiments (see also Example 5): 1) Crosslinking of CHO rEBP to colon carcinoma cells naturally expressing the *eck* receptor or to CHO cells transfected with the *eck* gene; 2) equilibrium binding studies of CHO rEBP to *eck* receptors on colon carcinoma cells; and 3) stimulation 10 of *eck* receptor phosphorylation on colon carcinoma cells. Induction of receptor phosphorylation by CHO rEBP indicates that the ligand may be able to effect a biological response (e.g., growth or differentiation) in cells displaying the *eck* receptor.

15 It is apparent that EBP may be expressed in a number of different molecular weight forms, more than one of which may be biologically active. Various forms of EBP are produced naturally by human cell lines and by EBP gene-transfected host cells as shown in Figures 1A 20 and 1B. As shown in Figure 3, EBP from transfected CHO cells was isolated as two different molecular weight forms of 22 kDa (major) and 24 kDa (minor).

Characterization of these different forms revealed two distinct EBPs of 150 and 165 amino acids, designated 25 EBP¹⁻¹⁵⁹ and EBP¹⁻¹⁵⁹. Phosphoinositol-phospholipase C treatment of EBP-transfected CHO cell lines releases soluble EBP, strongly suggesting a glycolipid form of EBP. Isolated 27 kDa forms of EBP are susceptible to digestion with phospholipase D further suggesting that 30 these forms are solubilized forms of glycophospholipid-anchored EBP.

The invention provides for EBP having the activity of specifically binding to the *eck* receptor and having substantially the same amino acid sequence as 35 shown in SEQ. ID. NO. 1. The term "substantially the same amino acid sequence" as used herein refers to

deletions or substitutions of amino acids in SEQ. ID. NO. 1 such that the resulting polypeptides specifically bind the *eck* receptor. As described above, EBP also induces phosphorylation of the *eck* receptor. However, 5 the present invention encompasses polypeptides which bind the *eck* receptor and may or may not induce receptor phosphorylation. In a preferred embodiment, EBP has a portion of the amino acid sequence as shown in SEQ. ID. NO. 1. For example, EBP has the amino acid sequence as 10 shown in SEQ ID. NO. 1 terminating at position 150 or has substantially the same amino acid sequence as shown in SEQ. ID. NO. 1 Preferably, EBP is EBP¹⁻¹⁵⁰, that is, it has the amino acid sequence from positions +1 to 150 as shown in SEQ. ID. NO. 1.

15 An EBP which has substantially the same amino acid sequence as shown in SEQ. ID. NO. 1 and has a methionine residue at position -1 is also included. [Met-1] EBP¹⁻¹⁵⁰ and [Met-1] EBP¹⁻¹⁵⁹ are examples. Also provided for are DNA sequence encoding same. A 20 truncated DNA sequence encoding amino acid residues +1 to 150 as shown in SEQ. ID. NO. 1 was constructed and expressed in *E. coli*. The resulting protein, [met-1] EBP¹⁻¹⁵⁰, binds to the *eck* receptor and induces receptor phosphorylation (Example 6).

25 Also encompassed by the invention are fragments and analogs of the polypeptide encoded by the amino acid sequence shown in SEQ. ID. NO. 1 wherein said fragments and analogs bind to the *eck* receptor, and DNA sequences encoding said fragments and analogs. Included 30 are fragments having deletions from the N-terminal or C-terminal ends of the polypeptide as shown in SEQ. ID. NO. 1 and deletions from internal regions. Examples of EBP fragments include EBP¹⁻¹⁶⁷, EBP¹⁻¹⁷¹ and EBP¹⁻¹⁸⁰ described in Example 5. Analogs include amino acid 35 substitutions at one or more sites in the polypeptide. Fragments and analogs of the invention are readily

constructed using recombinant DNA techniques which are known to those skilled in the art. The biological activity of the resulting fragments and analogs is readily tested by binding to eck soluble receptor or to 5 eck receptors on cell surfaces and by inducing phosphorylation of the eck receptor.

The invention also includes EBP characterized by being the product of procaryotic or eucaryotic expression of an exogenous DNA sequence, i.e., EBP is 10 recombinant EBP. Exogenous DNA sequences may be cDNA, genomic or synthetic DNA sequences. EBP may be expressed in bacterial, yeast, plant, insect or mammalian cells in culture or in transgenic animals. DNA vectors suitable for the expression of EBP in a 15 variety of host cells are known to one skilled in the art. Examples of such vectors are pDSR α 2 for the expression of EBP gene in CHO D- cells and pCFM1156 for the expression of EBP gene in *E. coli*.

EBP expression in *E. coli* results in the 20 formation of insoluble inclusion bodies. Recovery of biologically active EBP requires solubilization of EBP aggregates followed by refolding of the solubilized protein. Example 4C describes a refolding procedure for *E. coli* derived EBP which yields EBP active in eck-x 25 binding and eck phosphorylation. EBP refolding procedures may be modified to increase the activity of the renatured protein and to increase the yield of active EBP. Such modifications include changing the denaturant used to solubilize the inclusion body (e.g. 30 using guanidinium chloride vs. urea), the oxidizing agent (which may include oxidation reduction pairs such as oxidized and reduced glutathione), or the dilution protocol from the denaturant (e.g. EBP may be diluted at a different protein concentration into a detergent 35 containing buffer at a modified pH).

Also provided by the invention is a method for detecting a ligand present in crude samples, e.g., conditioned medium, which is capable of binding a receptor. The method comprises the steps of:

- 5 a) immobilizing a purified ligand binding domain of the receptor;
- b) contacting the immobilized receptor with conditioned medium containing the ligand; and
- c) monitoring the binding of the ligand to the
- 10 immobilized receptor by a surface plasmon resonance detection system.

As described in Example 2, this method provides a rapid and sensitive screening for eck receptor binding activity in cell supernatants. The 15 results of this screening are shown in Table 1. Although the method is used to detect eck binding activity, it may be generally applied to any receptor-ligand interaction. Any ligand binding domain of a receptor may be immobilized for the isolation of 20 receptor binding proteins. In a preferred embodiment, the ligand binding domain is the extracellular domain or a fragment or analog thereof which is competent for binding. In addition to screening cell supernatants, the method may also be used to screen mixtures of random 25 sequence peptides for receptor binding.

The invention provides, for the first time, a method of modulating the endogenous enzymatic activity of an eck receptor. Said method comprises administering to a mammal an effective amount of a ligand to the eck 30 receptor to modulate the enzymatic activity of said receptor. eck receptor enzymatic activity regulates cellular functions comprising differentiation, proliferation and metabolism. In a preferred embodiment, EBP, or a fragment or analog thereof, is the 35 ligand. However, other ligands may also be used in modulating eck receptor activity, for example,

polypeptides not related to EBP, or peptides and non-protein organic molecules.

Also encompassed by the invention is a method for identifying compounds that modulate the activity of an eck receptor. Said method comprises the steps of:

5 a) exposing cells exhibiting the receptor to known ligands for a time sufficient to allow formation of receptor-ligand complexes and induce signal transduction;

10 b) determining the extent of activity within the cells; and

c) comparing the measured activity to the activity in cells not exposed to the ligand.

Eck receptor activity may be detected by changes in 15 target cell proliferation, differentiation or metabolism. A description of methods relating to the modulation of eck receptor activity on hematopoietic progenitor cells, colon crypt cells and hepatocytes appears in Example 9.

20 The invention also encompasses an isolated eck receptor-ligand complex which results from the interaction of the eck receptor with a ligand such as EBP. The interaction may result in activation of the receptor and transduction of a signal which modulates 25 the physiological state of the receptor-bearing cells. Preferably, the ligand acts as a growth factor to stimulate the proliferation of target cells.

Alternatively, ligand binding may not activate the eck receptor. In this instance, the ligand may act as an 30 antagonist for other molecules which activate the receptor and induce signal transduction.

The eck receptor is expressed primarily in tissues containing significant amounts of epithelial cells (e.g. lung and intestine) and in cell lines 35 derived from epithelial cells (Lindberg et al., *supra*). A ligand of the eck receptor may stimulate either the

growth or differentiation of cells expressing the receptor. A ligand which induces differentiation of cells bearing the eck receptor may be useful in the treatment of certain types of cancers, particularly

5 those resulting from proliferation of epithelial cells. An eck receptor ligand may be used alone or in combination with standard chemotherapy or radiation therapy for cancer treatment.

EBP interaction with the eck receptor may be

10 involved in the development of a cancerous state through stimulation of cell growth or may promote metastasis by stimulating cell mobility and adhesion. Several

strategies are available for modulating the biological effects of EBP. Fragments or analogs of EBP which bind

15 to but do not activate the eck receptor are useful as EBP antagonists. Administration of an EBP antagonist having affinity for the eck receptor will block receptor binding and activation by circulating EBP.

Administration of soluble eck receptor may also be used

20 to counteract the biological effects of EBP. Soluble eck receptor will compete with cell surface receptors for binding to EBP and thereby reduce the extent of eck receptor activation by EBP. Soluble eck receptors suitable for therapeutic use include the receptor

25 protein described in Example 1 as well as fragments and analogs thereof which bind EBP. In addition, monoclonal antibodies directed either to EBP or to the eck receptor may be useful in blocking the interactions of EBP with eck receptors on cell surfaces.

30 Expression of the EBP gene in endothelial cells has been shown to be stimulated by TNF- α and IL-1 β , two proinflammatory cytokines which activate various functions in endothelial cells as part of the inflammatory response (Holzman et al. supra). A

35 treatment comprising the administration of soluble eck receptor to reduce levels of EBP that are increased

during the inflammatory response may be useful in controlling inflammation.

A method for the treatment of a wound in a mammal comprising administering a therapeutically effective amount of an eck receptor ligand is provided. As shown in Example 9A, EBP promoted an increase in tissue wet weight, total protein, total DNA, and total glycosaminoglycan in the rat wound chamber assay. Since EBP is expressed early in the inflammatory response, it could play a role in the recruitment of epithelial cells to the site of an injury.

A method for increasing hematopoiesis in a mammal comprising administering a therapeutically effective amount of an eck receptor ligand is also provided. As shown in Example 9B, EBP in combination with interleukin-3 (IL-3) shows a significant enhancement of CFU-Cs in mouse bone marrow cultures. EBP would be useful in restoring hematopoiesis when myelosuppression has occurred, either as a result of a disease or after exposure to myelosuppressive agents, such as chemotherapeutic drugs or agents. In a preferred embodiment, a therapeutically effective amount of EBP is used in combination with a therapeutically effective amount of IL-3 for increasing hematopoiesis.

Also included is a method for stimulating the proliferation of colon cells in a mammal comprising administering a therapeutically effective amount of an eck receptor ligand. As shown in Example 9C, EBP stimulates cell proliferation in a colon crypt assay. An eck receptor ligand such as EBP would be useful in alleviating gut toxicity following chemotherapy.

A method for stimulating proliferation of hepatocytes comprising administering a therapeutically effective amount of an eck receptor ligand is provided. Example 9D shows stimulation of hepatocytes by EBP. This stimulation is comparable to that seen in the same

assay with acidic fibroblast growth factor (aFGF), a known hepatocyte growth factor. Treatment with an eck receptor ligand is useful for repairing liver damage resulting from disease or injury.

5 As shown in Example 10, EBP promotes neural cell survival in five different rat cell culture systems: embryonic day (E)16 midbrain, E20 mesencephalon, E20 hippocampus, E15 spinal cord and postnatal day (P)5 locus coeruleus. These culture

10 systems are used to study specific neuron types: midbrain and mesenecephalon cultures contain dopamingeric, tyrosine hydroxylase (TH)-positive neurons; hippocampus cultures contain pyramidal neurons; spinal cord cultures contain motor neurons; and locus

15 coeruleus cultures contain noradrenergic, TH-positive neurons. The most pronounced effect of EBP was on survival of motor neurons in spinal cord cultures. Further studies of EBP action on E15 spinal cord cultures revealed that EBP acted through the eck

20 receptor to promote both motor neuron survival and dendrite outgrowth in a dose-dependent manner. EBP activity on a variety of neurons suggests it may be important in modulating the growth and/or differentiation of cell types in the nervous system.

25 In vitro cultures of cells taken from specific areas of the brain form the basis for in vivo models of certain neurological disorders. The relationship between the culture systems used herein, in vivo models and neurological disorders is described below.

30 Systemic administration of the neurotoxin MPTP (1-methyl-4-phenyl-1,2,3,6-tetrahydropyridine) destroys nigrostriatal dopamingeric neurons (Heikkla et al., Science 224, 1451-1453 (1984), Langston et al., Brain Res. 292, 390-394 (1984), Davis et al., Psychiatr. Res. 1, 249-254 (1979)) and induces a Parkinsonian syndrome in monkeys and humans. Thus MPTP-injected rats provide

one model for studying effects of various factors in Parkinson's related disorders. Another model for Parkinson's is 6-hydroxydopamine-induced lesions of the nigrostriatal dopamine system (Bjorklund et al., Trends

5 Neurosci. 10, 509 (1987)). Both MPTP and 6-hydroxydopamine-induced destruction of dopameric neurons may be reversed either by administration of purified neurotrophic factors (e.g., CNTF) or by grafting with fetal nigral neurons.

10 Ischemia-like conditions in vitro can be induced by culturing cells in medium purged with N₂ to deplete oxygen. Hippocampal neurons exposed to such conditions usually die within 24 hours. Similarly, an in vivo model for ischemia has been established by 15 exposing rat neonates to nitrogen (Speiser et al., Behav. Brain Res. 1, 379-382 (1983)).

Many neurodegenerative processes, including motor neuron degeneration characteristic of amyotrophic lateral sclerosis (ALS), demonstrate an aberrant 20 accumulation of neurofilaments in neurons. Transgenic mice having increased levels of neurofilament expression show morphologic features of motor neuron disease. A transgenic mouse containing a human genomic fragment encoding the neurofilament heavy (NF-H) gene can produce 25 up to two-fold higher levels of NF-H protein than animals having the endogenous gene. By 3 to 4 months of age, NF-H transgenics progressively develop neurological defects and abnormal neurofilamentous swellings characteristic of ALS (Coté et al., Cell 75, 35-46 30 (1993). In addition, Xu et al. (Cell 73, 23-33 (1993)) constructed transgenic mice expressing elevated levels of NF-L protein. In these animals, large motor neurons developed perikaryal neurofilament accumulations with phosphorylated NF-L. The number of degenerating axons 35 increased and muscles innervated by large motor neurons

exhibited severe atrophy coincident with the accumulation of perikaryal neurofilaments.

The polypeptides of the invention may be used to treat a variety of neurological disorders resulting

- 5 from disease or injury to neural or non-neural cells. In particular, EBP may be used to protect or prevent degeneration of motor neurons as is commonly observed in ALS and spinal cord injuries. EBP may be used alone, or in combination with other neurotrophic factors such as
- 10 ciliary neurotrophic factor (CNTF), brain derived neurotrophic factor (BDNF), glial derived neurotrophic factor (GDNF), nerve growth factor (NGF), insulin-like growth factor (IGF-1) or neurotrophin-3 (NT-3) for the treatment of motor neuron degeneration. EBP may also be
- 15 used to protect or prevent loss of neural cell function associated with disease or injury affecting dopaminergic, pyramidal and noradrenergic neurons. Conditions associated with a decrease or loss of function of these neurons include Parkinson's disease,
- 20 ischemia, or Alzheimer's disease. Other conditions treatable by EBP include Huntington's disease, multiple sclerosis, nerve trauma and peripheral neuropathies such as diabetic and chemotherapy-induced neuropathies. EBP may be used alone or in combination with other agents
- 25 for treatment of these diseases.

EBP may also be used to maintain in culture the growth and/or differentiation of cells of the nervous system (neural cells and glial cells). EBP, or a biologically active analog or fragment thereof, may be

- 30 added directly to an appropriate cell culture media. In particular, EBP may be used in culturing fetal neurons for transplantation into patients having damaged nervous system tissue. For example, embryonic dopaminergic neurons can be incorporated into adult brain and such
- 35 grafts can alleviate behavioral disorders. Growth

- 21 -

and/or differentiation in culture of other neurons can also be supported by addition of EBP.

The invention provides for pharmaceutical

5 compositions comprising therapeutically effective amounts of an eck receptor ligand together with pharmaceutically acceptable diluents, carriers, preservatives, emulsifiers and/or solubilizers. A "therapeutically effective amount" as used herein refers
10 to that amount which provides therapeutic effect for a given condition and administration regimen. It is expected that one skilled in the art would be able to determine a therapeutically effective amount of an eck receptor ligand for any given condition being treated.

15 Pharmaceutical compositions include diluents of various buffers (e.g., Tris, acetate, phosphate), solubilizers (e.g., Tween, Polysorbate), carriers such as human serum albumin, preservatives (thimerosol, benzyl alcohol) and anti-oxidants such as ascorbic acid.

20 As shown in Example 7, the ability of purified and diluted EBP to bind to soluble eck receptor is prolonged when EBP is formulated in the presence of a stabilizing agent. The stabilizing agent may be a detergent, such as tween-20, tween-80, NP-40 or Triton X-100. EBP may
25 also be incorporated into particulate preparations of polymeric compounds for controlled delivery to a patient over an extended period of time. A more extensive survey of components in pharmaceutical compositions is found in Remington's Pharmaceutical Sciences, 18th ed.

30 A.R. Gennaro, ed. Mack, Easton, PA (1990).

EBP may be administered by injection, either subcutaneous, intravenous or intramuscular, or by oral or nasal administration. The route of administration will depend upon the particular condition being treated.

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The following examples are offered to more fully illustrate the invention, but are not construed as limiting the scope thereof.

5

EXAMPLE 1

Production of eck receptor extracellular domain

A. Construction of an eck-x expression plasmid

10 A plasmid for mammalian expression of the extracellular domain of eck was generated in several steps beginning with pGEM3Z-eck, a 3.4kb EcoRI-Kpn I subclone of the eck cDNA (Lindberg et al. *supra*). Oligonucleotides 317-11 (5'-AGCTTAGATCTCC-3'; SEQ. ID. NO. 7) and 317-12 (5'-AATTGGAGATCTA-3'; SEQ. ID. NO. 8) were kinased and ligated to the 1.7kb EcoRI fragment of pGEM3Z-eck and pGEM4Z which had been digested with Hind III and EcoRI. A clone was selected which had the oligonucleotides added only to the 5' end of eck.

15 20 Characteristics of this clone include the addition of Hind III and Bgl II sites and deletion of the 5' EcoRI site adjacent to the eck sequence. The insert from this clone was isolated following digestion with Hind III and EcoRI and ligated to kinased oligonucleotides:

25

317-9 5'-AATTCCAGACGCTGTCCCCGGAGGGATCCGGCAACTGAG-3'

(SEQ. ID. NO. 9) and

317-10 5'-TCGACTCAGTTGCCGGATCCCTCCGGGGACAGCGTCTGG-3

(SEQ. ID. NO. 10)

30

with pGEM4Z digested with Hind III and Sal I. This added a Bam H1 site, a TGA stop codon following Asn⁵³⁴ and a Sal I restriction enzyme site. The Hind III-Sal I fragment containing the coding sequence for the external domain of eck was then transferred to pDSR α 2 (deClerk et al. *J. Biol. Chem.* 266, 3893 (1991)).

B. Mammalian cell expression of eck-x

The expression plasmid pDSR α -eck-x was

introduced in CHO cells by calcium mediated transfection

5 (Wigler et al. *Cell* 11, 233 (1977)). Individual colonies were selected based upon expression of the dihydrofolate reductase (DHFR) gene in the plasmid and one clone, designated 21.021 was chosen for amplification. Expression of the eck gene was monitored

10 by RNA hybridization (Hunt et al. *Exp. Hematol.* 19, 779 (1991)).

Amplification of eck expression was done in 10 nM methotrexate. Cell line 21.02 was expanded for production of eck-x. Roller bottles were seeded at 2 x 15 10⁷ cells in 200 ml DMEM:Ham's F12 (1:1) supplemented with non-essential amino acids, 10 nM methotrexate and 5% FBS. Cells reached confluence in 3 days at which time fresh media lacking 5% FBS was added. Conditioned media was harvested and replaced after seven days and a 20 second harvest was taken after fourteen days.

C. Purification of eck-x

Conditioned medium from 21.02 cells was concentrated and diafiltered against 10 mM Tris-HCl, pH 25 7.4 using a 10,000 MWCO spiral wound filter (S1Y10, Amicon, Danvers, MA). The 50 mL concentrate was loaded onto an anion exchange column (Hema-Q, 10 μ m particle size, 1.6 x 12 cm, Separon, Sunnyvale, CA) and eluted with a linear gradient of 0-0.5 M NaCl in 10 mM Tris-HCl, pH 7.4. Fractions were analyzed by SDS-PAGE and western blotting using a rabbit antiserum generated against a synthetic N-terminal peptide of eck-x. Fractions containing eck-x were pooled, dialyzed against 10 mM Tris-HCl, pH 7.4, reloaded onto the Hema-Q 30 column, and eluted and analyzed as before. The resulting pool was concentrated to 3 mL (centriprep-10,

Amicon, Danvers, MA) and applied to a Superdex 200 (Pharmacia, Piscataway, NJ) gel filtration column (2.2 x 90 cm, flow rate 1.0 ml/min) equilibrated in PBS. A pool containing the purified eck-x was made and served 5 as the basis of further experiments.

EXAMPLE 2
Screening of conditioned media
for binding to the eck extracellular domain

10

Interactions with eck-x were measured on a surface plasmon resonance detector system (BIAcore, Pharmacia Biosensor, Piscataway, NJ) using procedures recommended by the manufacturer. The dextran surface of 15 the sensor chip was activated by injecting 35 μ l of 0.2M 1-ethyl-3-(3-dimethylaminopropyl)carbodiimide-HCl, 0.05M N-hydroxysuccinimide at a flow rate of 5 μ l/min. The purified eck-x (0.2 mg/ml in 10 mM sodium acetate, pH 4.0) was immobilized by two consecutive 50 μ l 20 injections at 5 μ l/min. Unreacted binding sites were blocked by injection of 1M ethanolamine, pH 8.5. The surface was washed overnight in running buffer (HBS, 10 mM Hepes, 150 mM NaCl, 3.4 mM EDTA, 0.005% Tween 20, pH 7.4) until a stable baseline was achieved. Typical 25 immobilizations resulted in the establishment of baselines 6000-8000 response units above original values. 50 μ l samples of various conditioned media, cultivated under serum free conditions and concentrated five- to forty-fold (centricon-10, Amicon, Danvers, MA), 30 were injected at a flow rate of 10 μ l/min. Sample response was measured at report points on the sensorgram corresponding to 20 seconds after the conclusion of each injection. The immobilized eck-x surface was regenerated between samples by 50 μ l injections of 25mM 35 3-(cyclohexylamino)-1-propanesulfonic acid, pH 10.4.

- 25 -

Purified eck-x immobilized on a BIACore sensor chip was used to screen concentrated conditioned media for receptor binding activity. Binding activity was observed in several conditioned media, including those 5 from HCT-8, SK-BR-3, and HT-29 cell lines. (see Table 1)

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Table 1. Testing of cell culture supernatants by BIACore and anti-EBP Western blot

			eck-x Binding Activity (BIACore Response units)	Anti-EBP Western
5	<u>Cell line</u>	<u>Concentration</u>		
	A704	40X	49	-
	TE671	40X	115	-
	CCD18CO	40X	25	-
	CCFSTTG1	40X	35	-
10	HCT-8	40X	180	++
	GMO-0948	40X	10	-
	SK-BR-3	40X	270	++
	HT-29	40X	310	++
	MDA-MB-453	30X	80	++
15	FF-1	30X	55	-
	WS-1	25X	55	-
	BRL-3A	25X	125	-
	GMO1391	25X	20	-
	HT-1080	20X	230	+
20	AG-2804	20X	170	+
	BUD-8	20X	-10	-
	AG-3022	20X	175	+
	HFL-1	20X	15	-
	LIM-1863	20X	75	-
25	PAEC	20X	-10	-
	HOS	10X	95	-
	33C0	10X	-10	-

30 Samples (50 μ l injections) were tested for binding to immobilized eck-x using BIACore, as described in Example 2. Aliquots (10 μ l) of the same samples were analyzed retrospectively with rabbit anti-EBP (*E. coli*) antiserum.

EXAMPLE 3

Purification and Characterization of an eck receptor
binding protein (EBP) from conditioned medium.

5

A. Immobilized eck-x receptor affinity
chromatography.

Purified eck-x was dialyzed against 0.1M NaHCO₃, 0.5M NaCl, pH 8.3 and brought to a final

10 concentration of 2 mg/ml. The protein was immobilized on CNBr-activated Sepharose 4B (Pharmacia, Piscataway, NJ) at a ligand density of 1 mg eck-x per ml of gel (Kenny et al. in *New Protein Techniques*, J.M. Walker, ed. The Humana Press, Clifton, NJ. (1988)).

15 Conditioned medium from SK-BR-3 or HCT-8 cell lines was concentrated twenty fold and diafiltered against PBS (S1Y10 spiral cartridge, Amicon). The concentrate was loaded directly onto columns of immobilized eck-x (1 x 1 cm, 1mg eck-x per ml resin) at 20 a flow rate of 0.1 ml/min. The column was washed with 10 ml of PBS, followed by elution with 0.05 M sodium acetate, 0.5 M NaCl, pH 4.0. The elution pool was brought to 0.01% SDS, concentrated, and buffer exchanged against 10 mM Tris-HCl, pH 8.0 in a centricon-10 25 ultrafiltration device (Amicon). Samples were mixed with SDS-PAGE sample buffer, harvested from the centricon-10, and loaded directly onto polyacrylamide gels. Gels were stained with silver (Merrill Meth. *Enzymol.* 182, 477 (1991)) or blotted onto PVDF membranes (Problot, Applied Biosystems, Foster City, CA) for 30 N-terminal sequence analysis (Fausset et al. *Electrophoresis* 12, 22 (1991)).

An SDS-PAGE analysis of a typical run is shown in Figure 1. The pH 4.0 elution of the column, shown in 35 lane 5, displays a significant enrichment for several proteins with apparent molecular weights of 21-27 kDa.

These proteins were not detected when a similar volume of unconditioned medium was passed over the same column, indicating that the 21-27 kDa proteins were produced by the cell lines. In contrast, the higher molecular weight proteins present in the pH 4.0 elution fractions of HCT-8 or SKBR-3 conditioned medium were also observed in the unconditioned medium. These proteins represent nonspecific interactions with the column, and originate from the serum used for cell culture.

10

B. N-terminal sequence analysis of EBP.

N-terminal sequence analysis was performed on a liquid-pulse automatic sequencer (model 477, Applied Biosystems, Foster City, CA). The resulting phenylthiohydantoinyl amino acids were analyzed by on-line microbore high performance liquid chromatography (Model 123, Applied Biosystems) using a Brownlee C-18 reverse-phase column (0.21 x 25 cm). The sequencing cycles and optimization for sequence analysis of PVDF blots were based on recommendations supplied by Applied Biosystems.

15
20
25

N-terminal sequence analysis of the electroblotted proteins in the 21-27 kDa region of the gel revealed a single sequence (SEQ. ID. NO. 14):

NH₂-Asp-Arg-His-Thr-Val-Phe-Trp-[Asn]-Ser-Ser-Asn-Pro-Lys-Phe-Arg-Asn-Glu-Asp-Tyr-Thr-Ile-His-Val-Gln

30

A computer based homology search of the NBRF protein database (Devereux et al. *Nucleic Acids Res.* 12, 387 (1984)) resulted in the unambiguous assignment of this sequence to EBP (Holzman et al. supra).

35

C. Structural characterization of EBP.

Since N-terminal sequencing detected a single sequence, the multiple forms of EBP observed by SDS-PAGE

probably arise from post-translational modifications at other regions of the molecule. The sequencing yield of cycle 8 (N) was greatly diminished, indicating efficient glycosylation at this site. However, the apparent

5 heterogeneity of the protein may not be fully attributable to glycosylation differences, since digestion of rEBP with combinations of N-glycanase, neuraminidase, and O-glycanase resulted in a mixture of forms with M_r 17-19 kDa, when analyzed by SDS-PAGE.

10 Since the EBP gene codes for a protein of 22kDa (Holzman et al. *ibid*), this observation suggested that EBP might be subject to proteolytic processing.

D. Interactions of EBP with soluble eck
15 receptor.

Gel filtration analysis of the pH 4.0 eluted pool demonstrated that all of the eck-binding activity, as measured by BIAcore response, could be attributed to material eluting with apparent molecular weight of 22
20 kDa (Figure 2). SDS-PAGE analysis of the fractions from this column confirmed that EBP was co-eluted with the receptor binding activity. In separate experiments, purified EBP did not bind to BIAcore surfaces activated with the extracellular domain of the
25 kit receptor, although these surfaces could bind rSCF, the kit ligand.

E. Screening of additional cell lines for eck
binding proteins.

30 Following the isolation and identification of EBP, antiserum to the protein was prepared, and a retrospective analysis of the original screening was performed (Table 1). Western blot analysis confirmed that EBP was present at high levels in three conditioned
35 media (SK-BR-3, HCT-8, and HT-29) which scored positive in the screening. Several other cell lines (AG-3022,

- 30 -

AG-2804, and HT-1080) scored positive, but only trace amounts of processed EBP could be detected by the Western analysis. These cell lines did produce a 28kDa protein which was detected by the anti-EBP antiserum.

5

EXAMPLE 4

Cloning, Expression and Characterization of EBP

Heat-disrupted phage from a human umbilical 10 vein endothelial cell (HUVEC) library (Clontech Laboratories, Palo Alto, CA) were used as a template for amplification of the human EBP gene by polymerase chain reaction (PCR) (Saiki et al. *Science* **230**, 1350 (1985); Mullis et al. *Cold Spring Harbor Symp. Quant. Biol.* **51**, 15 263). Primers were designed based on the published nucleic acid sequence of EBP (Holzman et al. *ibid*) to yield PCR fragments that could be inserted into either *E. coli* or CHO cell expression vectors.

20 A. Cloning of EBP for *E. coli* Expression
A gene for *E. coli* expression of the full length form of EBP was generated by PCR using oligonucleotide primers 386-4 and 386-5 as shown below:

25 386-4) 5' AAG CAT ATG GAT CGC CAC ACC GTC TTC TGG 3'
(SEQ. ID. NO. 2)
386-5) 5' GAA GGA TCC TTA TCA CGG GGT TTG CAG CAG CAG
AA 3' (SEQ. ID. NO. 3)

30 This form lacked the signal peptide and included an initiator methionine as well as restriction sites necessary for cloning into the expression plasmid pCFM1156 (Fox et al. *J. Biol. Chem.* **263**, 18452 (1988)).
A 10 μ l aliquot of the λ gt11/HUVEC library (Clontech)
35 was heat treated at 70° C for 5 minutes then quick-cooled on wet ice. The disrupted phage were used as the

template for a PCR reaction containing 300 picomoles each of primers 386-4 and 386-5, 1X TaqI polymerase buffer (Promega, Madison, WI), 0.77 mM of each dNTP, and 2.5 units of TaqI polymerase (Promega) in a volume of

5 100 μ l. The product of this reaction was extracted with phenol/chloroform, ethanol precipitated, resuspended in 20 μ l of distilled water and then digested with the restriction endonucleases NdeI and BamHI (Boehringer Mannheim, Indianapolis, IN). This fragment was ligated
10 into the plasmid vector pCFM1156 which had been digested with the same two enzymes and transformed into the *E. coli* host strain FM5 (A.T.C.C. No. 53911). When transformed cells were temperature shifted from 30°C to 42°C, EBP was expressed at high levels.

15 A gene designed to express the 150 amino acid form of EBP in *E. coli* was constructed as described for the full-length gene except that oligonucleotide 469-11 was used in PCR instead of 386-5. Oligonucleotide 469-11 has the sequence:

20 5' GAAGGATCCCTATTATGCTGCAAGTCTCTCTCCTG 3'
(SEQ. ID. NO. 4)

B. Cloning of EBP for CHO cell expression

25 Total RNA was isolated from the cell line SK-BR-3, and used to prepare cDNA. Three μ g of total RNA was mixed with 3 μ g of random primer (Gibco BRL, Gaithersburg, MD), incubated at 65°C for 5 min, then cooled briefly on ice. The RNA-primer mixture was then
30 used in a cDNA reaction which consisted of 50 mM Tris-HCl (pH 8.3), 75 mM KCl, 3 mM MgCl₂, 10 mM DTT, 125 μ M of each dNTP (dATP, dCTP, dGTP, dTTP), 200 units of reverse transcriptase (Superscript, BRL), in a final reaction volume of 20 μ l. The reaction was incubated at
35 37°C for 1 h.

Two oligonucleotides were synthesized and used with the SK-BR-3 cDNA to amplify the EBP coding region by PCR.

5 386-2) 5' GAA TTC AAG CTT CAG GCC CCG CGC TAT GGA G 3'
(SEQ. ID. NO. 5)
386-3) 5' GAA TTC TCT AGA TCA TCA CGG GGT TTG CAG CAG
CA 3' (SEQ. ID. NO. 6)

10 The PCR contained 1 μ l of the cDNA reaction, 500 ng of both of the above oligonucleotides, 10 mM Tris-HCl (pH 8.3), 50 mM KCl, 200 μ M of each dNTP, and 1.25 units of Taq polymerase (Perkin Elmer Cetus, CA). DNA was amplified for 35 cycles (94°C for 30 s, 50°C for 15 1 min, 72°C for 1 min), extracted 1 time with phenol, 1 time with phenol-chloroform, precipitated, pelleted by microcentrifugation, and digested with the restriction enzymes Hind III and Xba I (Boehringer Mannheim). The DNA was gel-purified (Geneclean II, Bio 101, La Jolla, CA) and ligated to the plasmid pDSR α 2 (deClerck et al., *ibid*) which had been previously digested with the same restriction enzymes. The ligated DNA was transfected into competent HB101 bacteria (BRL), and plasmid DNA was isolated (Qiagen, Chatsworth, CA). The DNA sequence was 20 confirmed by the dideoxy chain termination reaction (Sanger et al. *Proc. Natl. Acad. Sci. USA* 74 5463 (1977)) on double-stranded plasmid DNA using synthetic 25 primers that corresponded to the EBP DNA sequence.

Culture supernatants from CHO cells 30 transfected with the EBP gene displayed eck-x binding activity on the BIACore, and EBP could be recovered from the supernatants by immobilized eck-x receptor affinity chromatography. Untransfected CHO cells, or CHO cells 35 transfected with a EBP gene containing an internal deletion, displayed no receptor binding activity.

C. Purification of recombinant EBP from
E. coli and CHO cells

Recombinant EBP was purified from CHO cell culture supernatants by immobilized *eck-x* receptor

5 affinity chromatography as described in Example 3A. The purified EBP was dialyzed vs. PBS with either 5 mM CHAPS (for structural analysis and crosslinking studies) or 0.5 mg/ml BSA (for phosphorylation studies). The CHO cell-derived EBP purified by receptor affinity

10 chromatography contained two major bands, as well as a few minor bands (Figure 1B).

Recombinant EBP from CHO cells was also purified by conventional chromatography. The CHO cell culture supernatant was concentrated and diafiltered

15 against 10 mM Tris, pH 8.5 and applied to an anion exchange column (Q-Sepharose, Pharmacia-LKB). The column was eluted with a linear gradient of NaCl in 10 mM Tris-HCl, pH 8.5. Analysis of the fractions by western blotting showed that the two major EBP bands had

20 been separated from one another. Separate pools were made of fractions containing the major EBP bands, and the pools were further purified by gel filtration chromatography (Superdex-75, Pharmacia-LKB)

Recombinant EBP from *E. coli* was purified by

25 the following method. Cells expressing the EBP1-150 or EBP1-187 genes were suspended in 10 mM Tris-HCl, pH 7.4 and lysed using a French press. The lysate was centrifuged in a J6-B (JS-4.2 rotor) at 4000 rpm for 30 min. The insoluble pellets (containing either

30 unfolded EBP1-150 or EBP1-187) were saved for further processing. The pellets were suspended in 2% sodium deoxycholate, 5 mM EDTA, 10 mM Tris-HCl, pH 8.5, and mixed for 30 minutes at 4°C. The suspensions were centrifuged as above, and the supernatants discarded.

35 The insoluble pellets were suspended in 10 mM Tris-HCl, pH 7.4, mixed, and centrifuged as above. The insoluble

pellets were dissolved in 2% sarkosyl, 10 mM CAPS, pH 10 in order to solubilize EBP1-150 or EBP1-187. CuSO₄ was added to a final concentration of 50 μ M, and the mixtures were stirred overnight at 4°C, then treated

5 with Dowex 1X4 resin in order to remove the detergent.

SDS-PAGE analysis revealed that a large proportion of EBP1-150 or EBP1-187 had oxidized and was monomeric. However, gel filtration analysis of EBP1-187 showed that the protein behaves as a high molecular 10 weight noncovalent aggregate. In contrast, gel filtration analysis indicates that the refolded EBP1-150 behaves as a monomer or dimer.

EBP1-187 and EBP1-150 produced in *E. coli* were tested for binding to immobilized eck-x by BIACore as 15 described in Example 2. The EBP1-187 aggregate bound poorly, if at all, to the eck-x surface. Refolded EBP1-150 demonstrated high affinity for eck-x surfaces on the BIACore.

Alternatively, the following procedure was 20 used to re-fold EBP1-150 expressed in *E. coli*. Cell paste was suspended in 9 volumes (v/w) of cold Super-Q water. The suspended cell paste was lysed using a Gaulin homogenizer at a pressure of 9,000 psi. The lysate was immediately centrifuged at 3,500 X G, 4°C for 30 25 minutes. The supernatant was discarded and the pellet, containing EBP inclusion body, was saved. The pellet was suspended in 10 volumes (v/w) of 8M urea, 0.1M Tris, pH 8.5, and stirred for one hour. Centrifugation was then performed to remove the insoluble fraction.

30 Refolding was effected by two stepwise dilutions of the soluble inclusion body. First, the inclusion body was diluted into 10 volumes (v/w) of 3M urea, 0.1M Tris, pH 8.5, containing 0.0005% CuSO₄ as a oxidizing agent, at 4°C while stirring overnight. This material was diluted 35 with 3 volumes (v/v) of 20mM Tris, pH 9.2, and was incubated for 24 hrs with gentle stirring.

Centrifugation was performed at 15,000 X G, 4°C for 30 minutes to remove precipitate.

The supernatant was then applied into Q-Sepharose Fast Flow column and washed with five column 5 volumes of 20mM Tris, pH 9.2. The column was eluted with a linear gradient of NaCl from 0-0.5M in 20mM Tris, pH 9.2. Fractions containing EBP were pooled, concentrated, and subjected to Superdex-75 chromatography. The EBP was eluted with 1X PBS.

10 The resulting purified EBP had a specific activity that is 30-40% of purified CHO derived EBP as measured by its ability to bind to immobilized eck-x in a BIAcore assay. The *E.coli* produced EBP refolded and purified by this procedure induced the phosphorylation 15 of eck localized on cellular surfaces.

D. Characterization of recombinant EBP from *E. coli* and CHO cell expression

Recombinant EBP, purified by receptor 20 chromatography from CHO cell culture supernatants, or by RP-HPLC from *E. coli* was digested with trypsin and analyzed by RP-HPLC. Although the C-terminal peptide (aa 155-187) was recoverable from the EBP1-187 gene expressed in *E. coli*, it could not be detected in the 25 mammalian derived recombinant protein. Carboxypeptidase digestion of the purified CHO EBP indicated that the only detectable C-terminal sequence was -lys-arg-leu-alanine-alanine-COOH (SEQ. ID. NO. 13), indicating a terminus at amino acid 150.

30

E. Alternative Forms of EBP

EBP isolated from SK-BR-3 cell line as described in Example 3 migrated on SDS-PAGE in the range of 21-27 kDa (see Figure 1A). Recombinant EBP in CHO 35 cell supernatants existed as two major species and a few minor bands after eck-x chromatography (Example 4 and

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Figure 1B). Further characterization of the different molecular weight forms of CHO-derived EBP was undertaken. Purification of recombinant EBP from CHO cell supernatants revealed two bands of 22 and 24 kDa and a third minor band of 27 kDa (see Figure 3). Treatment of purified EBP with glycosidases did not change the relative migration of these bands suggesting that they did not arise simply by variation in N- or O-linked carbohydrate. C-terminal sequencing previously revealed the 22kDa band as a polypeptide of 150 amino acids designated EBP¹⁻¹⁵⁰. The 24 kDa band was found to be 159 amino acids long as evidenced by C-terminal sequencing. This form was designated EBP¹⁻¹⁵⁹.

CHO cells expressing EBP were studied for the presence of membrane-bound forms of EBP. The recombinant CHO cell line 36.44 was established by transfection of CH0d- cells with the plasmid pDSR α -EBP. Cells were grown in suspension media using DMEM:F12 media supplemented with 1X non-essential amino acids and 1X penicillin, streptomycin, glutamine with 10% heat inactivated dialyzed fetal bovine serum. Aliquots of 10⁶ cells were treated with 4 μ g/mL phospholipase C (Calbiochem, La Jolla, CA) in 1mL phosphate buffered saline at 37°C for various times. Cells were pelleted at 14,000 RPM for 1 minute. Supernatants were removed for analysis. Cell pellets were lysed in RIPA buffer (150 mM NaCl; 1% NP-40; 0.5% deoxycholate; 50 mM Tris-HCl pH 8.0; 0.1% SDS; 1.74 μ g/mL PMSF; 1ng/mL each of aprotinin, pepstatin and leupeptin; 18.4 μ g/mL orthovanadate). Samples were applied to a 14% Tris-Glycine gel, blotted to a PVDF membrane and probed with a rabbit anti-EBP polyclonal antibody. Figure 4 shows that EBP was released into the supernatant in the presence of phospholipase C. These experiments suggested that the 27 kDa form of EBP had a glycophospholipid anchor.

EXAMPLE 5
EBP Analogs

5 In addition to the different forms of recombinant EBP made from the full-length EBP gene, analogs of EBP were constructed having varying polypeptide lengths. In particular, EBPs having 167, 171 and 180 amino acids were constructed as follows.

10 Oligonucleotides 421-12, 421-13 and 421-14 were synthesized for use as PCR primers to introduce termination codons following amino acid 180, 171 and 167, respectively. PCR reactions were done as described in Example 4B using each of those primers and the pDSR α -

15 EBP plasmid and oligonucleotide 386-2.

421-12 5'-GAATTCTCTAGATTATCATGGAAGGAGCAGCACAGTCCAG-3'
(SEQ. ID. NO. 15)

421-13 5'-GAATTCTCTAGATTATCATGGGAAGAGGGCGTGGGCAGC-3'
(SEQ. ID. NO. 16)

421-14 5'-GAATTCTCTAGATTATCATGGGCAGCAGTGTGACCGATGC-3'
(SEQ. ID. NO. 17)

25 The resulting analogs were expressed in CHO cells transfected with the altered DNA sequences using procedures described for the expression of EBP. Cells were grown to confluence in the presence of serum whereupon the media was switched to serum-free and allowed to accumulate. At 48 hours the conditioned

30 medium was collected and the adherent cells were lysed. Aliquots of the conditioned media and lysates were fractionated by polyacrylamide gel electrophoresis and subjected to Western blotting. EBP¹⁻¹⁸⁷ and EBP¹⁻¹⁸⁰ displayed a similar distribution of protein reacting

35 with the antibody in lysates and supernatants. Cells expressing EBP¹⁻¹⁷¹ and EBP¹⁻¹⁶⁷ had accumulation of EBP in

the supernatants, but not in the lysates. EBP analogs are analyzed for binding to eck-x by BIACore as describe in Example 2 and for phosphorylation activity of eck receptor as described in Example 6.

5

EXAMPLE 6

Interactions of recombinant EBP with the eck receptor

A. Crosslinking studies.

10 CHO-cell derived EBP was radiolabelled with ^{125}I as described below for use in crosslinking and binding studies. Five or 10 μg of EBP in 0.1M sodium phosphate (NaPO_4 , pH 8.0) was added to 5 mCi of dried ^{125}I -Bolton-Hunter reagent (NEN, Boston, MA) in a final 15 volume of 50 μl or 100 μl , and the tube was incubated at 4°C for 1 h. The reaction was terminated by addition of 0.3 ml of 0.2M glycine in 0.1M NaPO_4 , followed by 20 incubation at 4°C for 5 min. Labeled protein was separated from unincorporated reagent by gel filtration chromatography on a 10 ml PD10 column containing Sephadex G-25 M (Pharmacia) equilibrated with 0.1M NaPO_4 - 0.25% gelatin. Specific activity of the ^{125}I -EBP ranged from 4 to 19 cpm/pg.

25 Crosslinking of EBP to either LIM 2405 (a cell line naturally expressing the eck receptor) or CHO 19.32 (Chinese hamster ovary cells transfected with a clone of the full length eck receptor) was carried out as follows. CHO cells were grown in suspension to a density of approximately 5×10^5 cells/ml in media. 30 LIM2405 cells were grown in RPMI 1640 media containing 5% FCS, 1 $\mu\text{g}/\text{ml}$ insulin, 1 $\mu\text{g}/\text{ml}$ hydrocortisone, 10 μM thioglycerol and 2 mM L-glutamine to approximately 90% confluence in T-175 flasks and removed by scraping for use in the crosslinking studies. Cells were spun down 35 and resuspended in PBS to give a single cell suspension. For each crosslinking reaction, 2×10^6 cells were mixed

with approximately 20 ng of ^{125}I -EBP in a total volume of 1 ml. This mixture was incubated at 4°C for 1 h to allow binding of EBP to cell surface receptors before the addition of 20 μl of 10mM disuccinimidyl suberate (DSS) as a crosslinking agent. Cells were then washed three times in binding buffer, collected by centrifugation, and the amount of radioactivity incorporated into the cell pellets was counted to assess the degree of crosslinking. The cells were then lysed by treatment with 100 μl PBS, 1 mM EDTA, 0.5% NP-40, 1 mM phenylmethylsulfonyl fluoride (PMSF, Sigma, St. Louis, MO) for 10 min at 4°C . The insoluble material was removed by centrifugation and the soluble fraction containing the receptor/ligand complex was collected. These samples were either run directly on SDS-PAGE or first immunoprecipitated with an antibody directed against the C-terminal portion of the eck receptor (Lindberg et al. *supra*). Competition with either unlabeled EBP or an irrelevant protein (FGF) was carried out by mixing the competitor with the labeled EBP prior to addition to the cells.

As shown in Figure 5, ^{125}I -rEBP could be crosslinked to CHO 19.32 cells (lane 1) but not to the untransfected cells (lane 2). Crosslinking resulted in the detection of a 145 kDa protein, as well as higher molecular weight forms which may represent receptor dimers or higher order complexes. Unlabelled rEBP at 50-fold molar excess was able to compete for binding and crosslinking (lane 3). In separate experiments, recombinant fibroblast growth factor at concentrations of 1 $\mu\text{g}/\text{mL}$ had no effect on rEBP crosslinking. Similar crosslinking results were obtained for the LIM 2405 cell line.

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B. Binding studies.

To measure association kinetics, CHO 19.32 cells (2×10^6 cells/ml) were incubated with 3.8 nM ^{125}I -EBP in PBS-BSA (1mg/ml), at 0°C. Aliquots were 5 removed, and cell-bound ^{125}I -EBP was determined by centrifugation through sucrose gradients. Nonspecific binding was measured from parallel reactions containing 380 nM unlabelled EBP.

Equilibrium binding constants were determined 10 by incubating CHO 19.32 or LIM 2405 cells (0.5×10^6 cells/ml) with varying amounts of ^{125}I -EBP at 0°C for 1 h, bound EBP was determined as above, and the data was analyzed by the method of Scatchard (*Annal. N.Y. Acad. Sci.* 51, 660 (1949)). Nonspecific binding was 15 determined from parallel reactions containing a 50 fold excess of unlabeled EBP.

A Scatchard analysis of the steady-state binding of ^{125}I -rEBP to LIM2405 cells revealed that 20 there was apparently a single class of receptors on the cell surface with a K_d of 2.8×10^{-8} M $\pm 0.3 \times 10^{-8}$. On average, the LIM2405 cells contained 1.3×10^6 EBP receptors at the cell surface. BIAcore analysis of EBP binding to immobilized eck-x surfaces resulted in an estimated K_d of 2.4×10^{-8} M $\pm 0.4 \times 10^{-8}$.

25

C. p130^{eck} autophosphorylation studies.

The LIM 2405 colorectal carcinoma cell line (Whitehead et al. *Immunol. and Cell Biol.* 70, 227 (1992)) was maintained in RPMI 1640 containing 5% FBS, 30 1 $\mu\text{g}/\text{ml}$ insulin, 10 $\mu\text{g}/\text{ml}$ hydrocortisone and 10 μM α -thioglycerol, and subpassaged by trypsination and dilution (1:5) into fresh media. Prior to assay 2.5×10^5 LIM 2405 cells were seeded into 6-well dishes (Falcon # 3046) and incubated for 24 hr at 37°C. The 35 media was discarded and replaced with serum-free RPMI 1640 containing 0.03% BSA, 1 $\mu\text{g}/\text{ml}$ insulin, 10 $\mu\text{g}/\text{ml}$

hydrocortisone and 10 μ M α -thioglycerol, then incubated for 12-18 hr. In some experiments the cell cultures were labelled with 32 P-orthophosphate (2 mCi/ml) in phosphate-free RPMI 1640 (Flow) for 2-3 hr prior to 5 treatment. Growth factor stock solutions were prediluted at varying concentrations into 2.0 ml of serum-free media, then warmed to 37°C. Cell cultures were removed from the incubator, and the supernatant media discarded. Treatments were promptly added and the 10 cell cultures incubated at 37°C for 10-15 min. The cultures were then removed from the incubator, placed on ice, and the culture supernatant aspirated.

The treated cell cultures were chilled to 0°C then washed once with ice-cold PBS (GIBCO). The 15 residual PBS was aspirated and the cells were lysed by the addition of 1.0 ml of ice-cold RIPA buffer (10 mM sodium phosphate, pH 7.4, 150 mM sodium chloride, 0.1 % sodium dodecyl sulfate, 1% NP-40, 1% deoxycholate, 1% Trasylol, 2 mM EDTA, 50 mM sodium fluoride and 100 mM 20 sodium orthovanadate). After a 10 min incubation the lysates were transferred to 1.5 ml tubes and clarified by centrifugation for 30 min at 10,000 X g. The clarified lysate supernatants were transferred to new tubes and immunoprecipitated with 1.0 μ g/ml of affinity 25 purified rabbit anti-Eck C-terminal domain antibody for 2 hr at 0°C. Immune complexes were adsorbed to Protein-G Sepharose beads (Pharmacia) at 4 °C for 30 min, washed twice with ice-cold RIPA buffer, once with 0.1 M Tris-HCl, pH 8.0, containing 0.5 M LiCl, and once with RIPA. 30 The resulting immunoprecipitates were solubilized with SDS-PAGE sample buffer and stored for further analysis..

The anti-eck immunoprecipitates from treated and untreated LIM 2405 cell lysates were resolved on 35 7.5% polyacrylamide gels as previously described (Boyle et al. *Meth. Enzymol.* 201, 110 (1991)). After electrophoresis, the gels were electroblotted (Kamps

Meth. Enzymol. 201, 110 (1991)) onto Immobilon P (Millipore) and the blots were incubated for 1 hr in Tris-buffered saline containing 0.1 % Tween-20 (TBST) and 5% BSA to block non-specific binding sites on the membrane. Primary antibodies, either anti-phosphotyrosine antibody (4G10, UBI, Lake Placid, NY), or anti-eck C-terminal, were diluted to 1.0 µg/ml in TBST containing 3% BSA, 1% ovalbumin and incubated with the blots for 1 hr at room temperature. After this, the blots were rinsed with TBST, then washed once for 10-15 min, then twice for 5 min, each with TBST. The blots were then incubated with a 1:5000 dilution of secondary antibody coupled to horseradish peroxidase (Amersham, Arlington Heights, IL) in TBST alone for 20-30 min, then washed as before using TBST. Immune complexes were detected by chemiluminescent exposure (ECL, Amersham) to Kodak X-OMAT X-ray film at room temperature for 0.5-5 min.

Eck receptor immunoprecipitates from ³²P-labelled LIM 2405 cells were resolved by SDS-PAGE, and the gel dried directly without fixation. After exposure to X-ray film the labelled eck receptor band was isolated and phosphoamino acid content determined as described (Boyle et al. *Meth. Enzymol.* 201, 110 (1991))

CHO cell-derived rEBP stimulated eck receptor phosphorylation in intact LIM 2405 cells in a dose-dependent manner, with an optimal concentration between 100 ng/ml and 1 mg/ml (Figure 6, upper panel). There also appeared to be a modest dose-dependent decrease in the total cellular eck protein levels (Figure 6, lower panel), suggesting down regulation of the receptor after exposure to soluble EBP. Treatment of LIM 2405 cells with EBP does not result in spurious phosphorylation of the EGF receptor, nor does EGF treatment induce eck phosphorylation. Furthermore, when total cellular protein from LIM 2405 cells treated with rEBP was

analyzed, the only induced phosphoprotein is a Mr 130 kd polypeptide that corresponds to the mature eck receptor.

rEBP¹⁻¹⁵⁰ from *E. coli* was also assayed for autophosphorylation of the eck receptor on LIM 2405 5 cells following the procedure used for CHO-cell derived rEBP. Upon treatment of cells with the same quantities of CHO-derived rEBP and *E. coli* derived EBP¹⁻¹⁵⁰, it was observed that both forms of recombinant EBP were active in inducing phosphorylation.

10

EXAMPLE 7

Formulation of Recombinant EBP

Measuring the ability of EBP to bind to the 15 immobilized soluble extracellular domain of eck using BIAcore, it was determined that dilute solutions of purified EBP rapidly lost the ability to bind to the eck receptor unless formulated with a protective agent such as a detergent. Recombinant CHO EBP diluted into PBS to 20 100 µg/ml and incubated for 2 hours at 3°C lost approximately 50% of its eck binding activity. This loss of activity can be avoided by formulating the EBP in a detergent such as 1mM CHAPS, 0.1% NP-40, 0.1% tween 20, 0.1% triton-X 100, or 0.1% tween 80. (see figure 7). 25 The loss of eck binding activity in diluted EBP can also be avoided by incubating the protein with other protein carriers such as fetal calf serum.

The eck binding activity of at EBP 2-5mg/ml kept in detergent solutions is stable for at least one 30 week at 3°C, but protein solutions in the 10-500µg/ml range will lose activity if stored at -20°C, or if they are subjected to multiple freeze thaw cycles.

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EXAMPLE 8
Expression of EBP and eck
receptor in tissues and cell lines

5 Expression of EBP has been studied at the mRNA level in various rat tissues and organs using procedures described in Lindberg et al., supra. EBP is expressed most highly in the lung, intestine, liver, ovary and kidney. Expression was also detected at lower levels in
10 muscle, stomach, and brain.

Expression studies have been done for both EBP and the eck receptor in cell lines. EBP expression was tested for by immunoblotting cell supernatants in a Western analysis with affinity purified anti-human EBP
15 monoclonal antibodies. As shown in Table 2, EBP is found in many carcinoma cells. eck expression was tested for by several methods, including immunoblotting of whole cell lysates and immunoprecipitation with anti-eck antibody from cell lysates. (Lindberg et al.,
20 supra) The results in Table 2 show that eck is expressed in many cell lines of epithelial origin, and in addition, is found in fibroblasts and melanoma cell lines.

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TABLE 2

Cell lines that express EBP:		
	Cell line	Cell type
10	CaCo2	Colon adenocarcinoma
	FADU	Squamous carcinoma
	T47D	Breast carcinoma
	MDAMD361	Breast adenocarcinoma
	THP-1	Monocytic leukemia
	SKBR3	Breast adenocarcinoma
15	CaOV4	adenocarcinoma
	MDAMB453	Breast adenocarcinoma
	Caki1	Kidney carcinoma
	HBL100	Breast
	HT29	Colon adenocarcinoma
	JEG1	Choriocarcinoma
20	293	Embryonic kidney
	A704	Kidney adenocarcinoma
	Caki2	Kidney adenocarcinoma
	CaOV3	Ovarian adenocarcinoma
	SKOV3	Ovarian adenocarcinoma
	A172	Glioblastoma
25	A431	Epidermal carcinoma
	BSC1	Kidney
	BT20	Breast carcinoma
	PC3	Prostate adenocarcinoma
	JAR	Choriocarcinoma
	A498	Kidney carcinoma
30	LNCaP	Prostate adenocarcinoma
	BT474	Breast carcinoma
	SW480	Colon adenocarcinoma
	SW620	Colon adenocarcinoma
	MCF7	Breast adenocarcinoma
	T24	Bladder carcinoma
35	5637	Bladder carcinoma
	Dul145	Prostate carcinoma
	SKNSH	Neuroblastoma
	L929	Connective tissue
	G401	Kidney Tumor

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TABLE 2 (Con't)

	5	Cell lines that express eck:	
		Cell line	Cell type
10	THP-1		Monocytic leukemia
	CCD11Lu		Lung
	HT29		Colon adenocarcinoma
	SKOV3		Ovarianadenocarcinoma
	A172		Glioblastoma
	A431		Epidermal carcinoma
15	JAR		Choriocarcinoma
	GM4312A		Fibroblast
	Wi38		Lung
	UT7		Premegakaryocyte
20	CHOK1		Ovary
	HS249T		Melanoma
	M14		Melanoma
	NIH3T3		Fibroblast

EXAMPLE 9
Biological Activities of EBP

A. Activity of EBP in Rat Wound Chamber Assay

5 The effects of recombinant CHO-derived and E.coli derived EBP on granulation tissue formation in subcutaneously implanted wound chambers in rats was studied.

10 Male Sprague-Dawley specific pathogen free rats (300-350g; Charles River Breeding Laboratories, Inc.) were used for this study. Rats were anesthetized with sodium pentobarbital (50 mg/kg body weight) by intraperitoneal injection. Using aseptic surgical technique, a 3 cm midline incision was made on the

15 dorsal surface of the rat. A single pocket was formed under the panniculus carnosus by blunt dissection on one side of the animal. A 3 cm long x 1 cm diameter sterile stainless steel wire mesh cylinder was then inserted subcutaneously. The wound chambers used were similar to

20 those described by Schilling et. al. (*Surgery* 46, 702-710 (1959)) and utilized by Hunt et. al. (*Am. J. Surg.* 114, 302-307 (1967)) as wound healing models. The incision was closed with wound clips. The rats survived the operation well with no evidence of postoperative

25 discomfort. Beginning 3 days after wound chamber implantation, the rats were randomly divided into 5 groups. At this time daily injections of 1) 10 µg CHO-derived EBP, 2) 1 µg CHO-derived EBP, 3) 8 µg E.coli-derived EBP, 4) 5 µg recombinant platelet derived growth

30 factor (PDGF), or 5) 0.1 ml sterile PBS and 1 mM CHAPS were begun and continued for a total of 9 days. The injections were made directly into the wound chamber through a silicone septum at the outer edge of the chamber. Twelve days after chamber implantation, the

35 rats were sacrificed by CO₂ asphyxiation. Immediately after sacrifice, the chambers were removed surgically

and carefully opened. The enclosed granulation tissue was then weighed, and stored at -70°C for future processing.

Granulation tissue samples were thawed and

5 homogenized with a Polytron homogenizer in 2 ml of ice-cold distilled water for approximately 1 minute. Next, 2 ml of ice-cold 10% trichloroacetic acid was added to the homogenate and incubated at 4°C for 1 hour. The TCA-precipitated samples were centrifuged (500g, 10

10 minutes) at 4°C, washed once with 2 ml of ice-cold 5% TCA, and finally washed with 2 ml of ice-cold 95% ethanol containing 50 mM sodium acetate. Samples were defatted twice with 2 ml of ethanol:ether (3:1, v/v) at 20°C. After each defatting procedure, samples were

15 centrifuged (500xg, 10 minutes) and the supernate discarded. The pellet was then dissolved in 1N sodium hydroxide and brought up to a volume of 10 ml.

Total protein was determined by taking an aliquot of the solubilized granulation tissue and

20 assaying the sample according to the method of Bradford (Anal. Biochem. 72, 248-251 (1976)) Bovine serum albumin (Sigma Chemical Co., St. Louis, MO) was used for a protein standard curve.

Total DNA content was determined as deoxy-

25 ribose by the colorimetric method of Burton (Biochem. J. 62, 315 (1956)). Briefly, a 1 ml aliquot of the solubilized sample (in N NaOH) was neutralized with the addition of 0.5 ml of 2 N HCl. A 1 ml aliquot of the neutralized solution was extracted in 10% perchloric

30 acid at 90°C for 15 minutes. A 1 ml portion of the final extract was added to 2 ml activated diphenylamine (Sigma Chemical, St. Louis, MO) reagent and absorbance at 600 nm was measured after overnight incubation at room temperature. Hydrolyzed calf thymus DNA (Sigma)

35 was used to construct the standard curve. The DNA content was measured as a rough index of the number of

cells in the wound chamber, with the realization that cell type and cell cycle status also influence DNA content.

Total glycosaminoglycans (GAGs) were 5 determined using chondroitin sulfate as a standard. A spectrophotometric assay for GAGs was run utilizing a change in absorption spectrum of the dye 1,9- dimethyl methylene blue (Farndale et al. Conn. Tiss. Res. 9, 247- 248 (1982)).

10 Total collagen content was determined as hydroxyproline (an index of collagen content) after hydrolysis of the solubilized granulation tissue in 6N HCl at 110°C for 24 hours. Aliquots of 200 µl sample hydrolyzate were dried down, reconstituted in 200 µl of 15 buffer and analyzed for hydroxy-L-proline by amino acid analysis using a Beckman 6300 amino acid analyzer. Quantitation was done using an external standard of hydroxy-L-proline (Sigma).

20 The data was analyzed by one-way analysis of variance. Significant differences were then analyzed comparing individual group means using a two-tailed unpaired student's t test. Statistical significance was defined as p<0.05. All values are expressed as mean ± SEM.

25 CHO-derived rEBP at a dose of 10 µg per chamber per day for 9 consecutive days and rPDGF at a dose of 5 µg per day (x 9 days) both significantly increased the wet weight, total protein, total DNA and total GAG content of the chamber granulation tissue as 30 compared to vehicle-treated (PBS and 1 mM CHAPS) control rats (see Table 3). All chambers were harvested 12 days after implantation. This timepoint is at the peak of granulation tissue formation and at the early stages of collagen formation. CHO-derived rEBP at a dose of 1 µg 35 per chamber per day showed a significant increase in granulation tissue wet weight and GAG content over

- 50 -

vehicle treated control rat chambers. However, there were no significant differences against control in the total protein, DNA, and hydroxyproline content for the 1 μ g rEBP dose.

5 The accumulation of collagen is probably the single most important factor contributing to wound strength. PDGF treated chambers showed an 82% increase in hydroxyproline content (and therefore collagen synthesis) over control chambers. CHO-derived rEBP

10 showed a 21% increase in hydroxyproline at 1 μ g/chamber/day, and a 35% increase in hydroxyproline at 10 μ g/chamber/day, although these increases were not statistically significant.

TABLE 3

Effects of CHO-Derived EBP on Granulation Tissue Formation in Wound Chambers in Rats

TREATMENT	WET WEIGHT (mg)	TOTAL PROTEIN (mg)	DNA (μg)	HYDROXY-PROLINE (μg)	TOTAL GLYCOSAMINO-GLYCANS (μg)	CHANGE IN BODY WEIGHT (g)
Control	158.6 ± 17.9	2.76 ± 0.27	153 ± 20	263.5 ± 29.1	383.3 ± 41.5	+53.8 ± 5.4
PDGF 5ug	417.4 ± 81.8**	7.46 ± 1.52**	356 ± 64**	478.4 ± 85.9*	725.2 ± 104.4**	+45.4 ± 2.8
CHO-EBP 10μg	398.2 ± 70.9**	7.15 ± 1.23**	650 ± 163*	354.5 ± 354.5	627.9 ± 63.7	+50.3 ± 5.2
CHO-EBP 1μg	238.0 ± 24.1*	3.88 ± 0.44	232 ± 41	318.7 ± 31.7	589.2 ± 68.4*	+48.5 ± 4.9

All Values are Mean ± SEM

*p<0.05 by two-tailed unpaired Student's t test vs. control group

**p<0.01 by two-tailed unpaired Student's t test vs. control group

B. Activity of EBP in Murine Hematopoiesis

Unfractionated bone marrow suspensions from BDF mice were plated into serum free culture medium (Iscove's modified Dulbecco's medium) in 0.3% agarose

5 and incubated at 37°C, 5% CO₂ for ten days at a cell concentration of 1X10⁵/ml in 96 well plates. Total volume per cell was 50 µl. EBP and other growth factors were added in the amounts indicated and colonies were scored at the tenth day of incubation. The results are

10 shown in Figure 8.

EBP at 1 µg/ml could potentiate murine IL-3 dependent murine CFU-C formation about 2-fold compared to IL-3 alone. CFU-C represents CFU-G, CFU-GM and CFU-M. EBP alone showed no stimulation of CFU-M or BFU-

15 E/CFU-E.

C. Activity of EBP in Colon Crypt Assay

Colons from five (BDF) mice were removed and

20 crypts isolated using a non enzymatic (EDTA) extraction

method. Briefly, colons are washed and allowed to sit

for 20 min. in a solution of PBS containing .04% sodium

hypochlorite. Crypts are isolated by incubating the

tissue for 1 hour at 37°C in a solution of PBS

containing 3mM EDTA and 0.5 mM DTT. Crypts are then

25 subjected to pancreatin digestion (0.2% in PBS) for 90

min. at 37°C in order to obtain a single cell

suspending. Cells are washed in PBS, counted and

viability determined by trypan blue exclusion (85% in

this experiment). Cells are then plated in a top layer

30 of 0.37% Sigma low melt agar onto a bottom layer of 0.5%

agar. The RPMI media used in the agar includes the

presence of 1X ITS (insulin, transferrin, and selenium,

Gibco). Incubations were done in the presence of 1%

fetal calf serum (FCS) and the indicated growth factors

35 at the following concentration: TGF α , 50ng/ml; bFGF,

60ng/ml; EBP, 500ng/ml. Control incubations lacked

growth factors and/or FCS. Each of the various culture conditions was performed in triplicate and scored every several days.

Positive results were obtained after crypt

5 cells were incubated with 1% FCS and EBP or 1% FCS and bFGF. In both conditions, the clusters of cells were large and the individual cells within the clusters appear healthy. In some cases the clusters were crypt-like shaped. When both EBP and bFGF were added together

10 with FCS, fewer and smaller clusters appeared compared to when either growth factor was added alone in the presence of 1% FCS. Initially, the combination of EBP and bFGF appeared to be inducing cell growth but this stimulation in growth was short lived. In the plates

15 with EBP alone (no serum) there were occasional large clusters, however these were looser, the cells were larger and roughly half the cells were nonviable within the cluster.

These results suggest that EBP is involved in

20 the proliferation, differentiation or reformation of colon crypt cells.

TABLE 4

Activity of EBP in Colon Crypt Assay

DAY	TGF α	TGF α +EBP	EBP	bFGF	EBP+bFGF	1%FCS+EBP	1%FCS+bFGF	1%FCS+ EBP+bFGF	1%FCS	NT
2	--	--	--	--	++	++	++1/2+	++	--	--
5	--	--	--	--	++	++	+++	+++	+	--
7	--	--	+/-	--	+/-	+++	++	++	--	--
9	--	--	+/-	--	++	+++	+++	++	--	--
12	--	--	+/-	--	++	+++	+++	++	--	--

NT - not treated

- 55 -

D. Activity of EBP on Primary Cultures of Hepatocytes

Hepatocytes were isolated by the *in situ* two step collagenase perfusion technique described by Seglen (*Methods in Toxicol.*, Vol. 1A, 231-243 (1993)). Briefly,

- 5 the perfused livers were dispersed in ice cold Hank's buffer, filtered through a nylon mesh, and hepatocytes separated from nonparenchymal cells by repeated centrifugation at 50 X g. The hepatocytes were determined to be greater than 85% viable by trypan blue
- 10 exclusion. The hepatocytes were cultured on plates coated with rat tail collagen and plated in Williams E containing 5% FCS, 10^{-7} M insulin, 10^{-8} M dexamethason, glutamine, penicillin and streptomycin.

Cells were allowed to attach for 3-4 hours in

- 15 serum containing media and then transferred to serum-free media. The appropriate concentrations of EBP or other growth factors were added and the cells were incubated for 24 to 48 hours in the presence of 3 H-thymidine. After incubation, the extent of
- 20 3 H-thymidine incorporation into cells was determined. The growth factors tested were keratinocyte growth factor (KGF) at 10 ng/ml, acidic FGF (aFGF) at .20 ng/ml, and EBP at 20ng/ml. The results are shown in Figure 9. The amount of 3 H-thymidine incorporation stimulated by
- 25 EBP is about the same as that induced by aFGF. The combination of KGF and EBP did not stimulate hepatocyte growth over the level observed by KGF alone. In this particular experiment, the serum free value was unusually high (about 3-fold).

EXAMPLE 10

Neurotrophic Activity of EBP

5 A. Promotion of neuronal survival and neurite outgrowth in embryonic rat spinal cord neurons

 Recombinant soluble EBP was produced in CHO cells and purified as described in Example 4. Monolayer cultures of dissociated cells were prepared from spinal

10 cords of 15-16 day-old Sprague-Dawley rat embryos as previously described (Magal et al., Dev. Brain Res. 63, 14-150 (1991)). Briefly, a single cell suspension was prepared from spinal cords and seeded at about 25,000 cells in 90 μ l per well in 96-well plates, sequentially

15 precoated with polyornithine (Sigma; 0.1 mg/ml) and laminin (Gibco; 1 mg/ml). The culture medium was Leibovitz L-15 medium, 5% heat-inactivated horse serum, 0.5% heat-inactivated fetal calf serum, sodium bicarbonate (2.5 g/L), D-glucose (9 g/L), L-glutamine

20 (2 mM), penicillin (100 mg/ml) and a mixture of amino acids and vitamins. Different concentrations of EBP were added to the cells at the time of seeding, in a volume of 10 μ l per well, completing the volume to 100 μ l/well. Media and treatments were renewed every

25 other day. Control cultures received 10 μ l of medium without EBP. At designated time periods, cultures were fixed with 4% paraformaldehyde for 30 min at room temperature, washed with PBS, permeabilized with 1% Triton X-100 and blocked for 30 min at room temperature

30 30 with 5% normal horse serum in PBS containing 0.1% Triton X-100. Anti-MAP2 mouse monoclonal IgG (Boehringer Mannheim), at 1:1000 dilution, was applied in the blocking solution overnight at 4°C. Subsequently

 cultures were incubated in biotinylated mouse IgG, at a

35 300-fold dilution for 1.5h at room temperature. Next, the cultures were incubated for 45 min. at room

temperature in avidin-biotin-peroxidase complex in PBS containing 0.1% triton X-100, washed again with PBS and reacted for 5 min. in 0.1M Tris-HCl containing 0.04% 3',3'-diaminobenzidine tetrachloride, 0.06% NiCl₂ and 5 0.02% H₂O₂. The effect of EBP on the survival of spinal cord neurons was quantified by counting all the MAP2 positive cells in the well.

10 Figure 10 shows that EBP increased neuronal survival after 9 days in culture in a dose-dependent manner. Survival was enhanced by as much as 84% with an ED₅₀ of less than 10 µg/ml. In addition, neurites in EBP-treated cultures were longer and more elaborated compared to control cultures (Figure 11 a through f).

15 B. Involvement of Eck receptor in EBP-mediated neurotrophic activity.

20 Partially purified spinal cord motor neuron cultures (approximately 70%-75% motor neurons) were prepared as previously described (Camu and Henderson, J. Neurosci. Methods 44, 59-70 (1992)) with slight modifications. Briefly, ventral spinal cords were dissected from 15 day old Sprague-Dawley rat embryos and incubated in 0.05% trypsin in PBS for 17 minutes at 37°C, after which a 10% volume of fetal calf serum was 25 added. Subsequently cells were resuspended in dissociation media composed of L15 medium without sodium bicarbonate (Gibco) supplemented with 5 µg/ml insulin, 0.1 mM putrescine, 0.1 mg/ml conalbumin, 30 nM sodium selenite, 20 nM progesterone, 20 mM glucose, 100 IU/ml penicillin, 100 µg/ml streptomycin, 0.1% BSA and 30 250 Units/ml of DNase. The tissue was dissociated by gentle trituration through a Gilson blue pipette tip until a single cell suspension was obtained. The resulting suspension was filtered through 40 µm nylon 35 mesh and applied on top of 4 ml of 6.8% metrizamide in 15 ml polystyrene tubes. The tubes were centrifuged

for 20 minutes at 1650 rpm in a bench-top Beckman centrifuge. Large cells, which formed a sharp band on the top of the metrizamide cushion, were washed in 4 volumes of the dissociation media and layered onto 5 2 ml of 4% BSA. The cells were centrifuged for 10 min at 800 rpm. The resulting cell pellet was resuspended in culture medium (DMEM/F12 and B27 (Gibco) supplemented with 10% fetal bovine serum), and subsequently plated in Terasaki wells (HLA plates, Nunc) pre-coated with 10 poly-ornithine and laminin), at a density of 6,000-10,000 cells/well in 90 μ l of medium. The treatments, which included the addition of EBP, EBP and anti-Eck antibodies, and finally EBP and anti-EBP antibodies, were added at 10X concentration in 10 μ l/well. The anti-Eck monoclonal antibodies were 15 obtained by using recombinant human Eck extracellular domain (ECK-X) prepared as described in Example 1, as the antigen. The antibodies were purified from ascites using protein A-sepharose. Anti-ECK1 and anti-ECK2 20 antibodies recognize different epitopes in human Eck. The anti-ECK1 antibody recognizes human and rat Eck while anti-ECK2 antibody recognizes only human Eck. After 3 days, the cultures were fixed in 2% paraformaldehyde for 15 minutes at room temperature. 25 Phase-bright cells with neuronal morphology and without vacuolar inclusions were counted in 2 crossing strips per well at 100X magnification, representing 20% of the well's surface area. Neurite length was measured from photographs as the distance between the cell soma and 30 the tip of the longest neurite, using the Jandel Video Analysis Software (JAVA).

Figure 12 shows that EBP acts through the Eck receptor to enhance neural survival and neurite outgrowth in cultures enriched for motor neurons. EBP 35 activity is abolished in the presence of the anti-ECK1

antibody or the anti-EBP antibody, but is not affected by addition of the anti-ECK2 antibody.

C. Effects of EBP on other neuron types.

5 Experiments similar to those described in Part A were performed on neural cultures derived from rat embryonic midbrain and mesencephalon (TH-positive dopaminergic neurons), hippocampus (pyramidal neurons) and postnatal locus coeruleus (TH-positive noradrenergic neurons). Preparation of rat day 16 midbrain cultures, rat day 20 mesencephalon cultures, rat day 20 hippocampus cultures and postnatal rat 4-5 day locus coeruleus cultures was essentially as described in Magal et al. *Neuroscience* 52, 867-881 (1993), Magal et al. 10 *Neuro Report* 4, 779-782 (1993), and Louis et al. *Eur. J. Neurosci.* 5, 1610-1621 (1993). The results presented in 15 Table 5 show that EBP mediates survival of neurons in all four cultures tested, proving that EBP can promote the survival of dopaminergic, pyramidal and 20 noradrenergic neurons.

TABLE 5

Neuronal Culture	Neuron Type	# of neurons/well (mean \pm S.E.)	
	dopaminergic/TH-positive	-EBP	+EBP
E16 midbrain		36.7 \pm 4.64 (5 days) ^a	62.3 \pm 2.62 (20ng/ml) ^b
E20 mesencephalon	dopaminergic/TH-positive	40.3 \pm 1.25 (3 days)	71.5 \pm 8.40 (1000ng/ml) 87.0 \pm 8.98 (3500 ng/ml) 57.7 \pm 1.25 (250 ng/ml)
E20 hippocampal	gabaergic/GABA-positive	948.5 \pm 65.5 (3 days)	1306.5 \pm 88.5 (200 ng/ml) 972.0 \pm 14.0 (50 ng/ml)
P5 locus coeruleus	noradrenergic/TH-positive	54.0 \pm 6.40 (4 days)	81.0 \pm 10.12 (500 ng/ml)

^a Number of days in culture \pm EBP^b Final concentration of EBP added to culture

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* * *

While the present invention has been described in terms of the preferred embodiments, it is understood 5 that variations and modifications will occur to those skilled in the art. Therefore, it is intended that the appended claims cover all such equivalent variations which come within the scope of the invention as claimed.

SEQUENCE LISTING

(1) GENERAL INFORMATION:

(i) APPLICANT: Amgen Inc.

(ii) TITLE OF INVENTION: ECK Receptor Ligands

(iii) NUMBER OF SEQUENCES: 17

(iv) CORRESPONDENCE ADDRESS:

- (A) ADDRESSEE: Amgen Inc.
- (B) STREET: 1840 Dehavilland Drive
- (C) CITY: Thousand Oaks
- (D) STATE: California
- (E) COUNTRY: U.S.A.
- (F) ZIP: 91320

(v) COMPUTER READABLE FORM:

- (A) MEDIUM TYPE: Floppy disk
- (B) COMPUTER: IBM PC compatible
- (C) OPERATING SYSTEM: PC-DOS/MS-DOS
- (D) SOFTWARE: PatentIn Release #1.0, Version #1.30

(vi) CURRENT APPLICATION DATA:

- (A) APPLICATION NUMBER:
- (B) FILING DATE:
- (C) CLASSIFICATION:

(viii) ATTORNEY/AGENT INFORMATION:

- (A) NAME: Winter, Robert B.
- (C) REFERENCE/DOCKET NUMBER: A-213-CIP2

(2) INFORMATION FOR SEQ ID NO:1:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 205 amino acids
- (B) TYPE: amino acid
- (C) STRANDEDNESS: single
- (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: protein

- 63 -

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:1:

Met Glu Phe Leu Trp Ala Pro Leu Leu Gly Leu Cys Cys Ser Leu Ala
 1 5 10 15

Ala Ala Asp Arg His Thr Val Phe Trp Asn Ser Ser Asn Pro Lys Phe
 20 25 30

Arg Asn Glu Asp Tyr Thr Ile His Val Gln Leu Asn Asp Tyr Val Asp
 35 40 45

Ile Ile Cys Pro His Tyr Glu Asp His Ser Val Ala Asp Ala Ala Met
 50 55 60

Glu Gln Tyr Ile Leu Tyr Leu Val Glu His Glu Glu Tyr Gln Leu Cys
 65 70 75 80

Gln Pro Gln Ser Lys Asp Gln Val Arg Trp Gln Cys Asn Arg Pro Ser
 85 90 95

Ala Lys His Gly Pro Glu Lys Leu Ser Glu Lys Phe Gln Arg Phe Thr
 100 105 110

Pro Phe Thr Leu Gly Lys Glu Phe Lys Glu Gly His Ser Tyr Tyr Tyr
 115 120 125

Ile Ser Lys Pro Ile His Gln His Glu Asp Arg Cys Leu Arg Leu Lys
 130 135 140

Val Thr Val Ser Gly Lys Ile Thr His Ser Pro Gln Ala His Val Asn
 145 150 155 160

Pro Gln Glu Lys Arg Leu Ala Ala Asp Asp Pro Glu Val Arg Val Leu
 165 170 175

His Ser Ile Gly His Ser Ala Ala Pro Arg Leu Phe Pro Leu Ala Trp
 180 185 190

Thr Val Leu Leu Leu Pro Leu Leu Leu Gln Thr Pro
 195 200 205

(2) INFORMATION FOR SEQ ID NO:2:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 30 base pairs
- (B) TYPE: nucleic acid
- (C) STRANDEDNESS: single
- (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: cDNA

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:2:

AAGCATATGG ATCGCCACAC CGTCTTCTGG

- 64 -

(2) INFORMATION FOR SEQ ID NO:3:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 35 base pairs
- (B) TYPE: nucleic acid
- (C) STRANDEDNESS: single
- (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: cDNA

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:3:

GAAGGGATCCT TATCACGGGG TTTGCAGCAG CAGAA

35

(2) INFORMATION FOR SEQ ID NO:4:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 36 base pairs
- (B) TYPE: nucleic acid
- (C) STRANDEDNESS: single
- (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: cDNA

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:4:

GAAGGGATCCC TATTATGCTG CAAGTCTCTT CTCCTG

36

(2) INFORMATION FOR SEQ ID NO:5:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 31 base pairs
- (B) TYPE: nucleic acid
- (C) STRANDEDNESS: single
- (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: cDNA

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:5:

GAATTCAAGC TTCAGGCCCC GCGCTATGGA G

31

(2) INFORMATION FOR SEQ ID NO:6:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 35 base pairs
- (B) TYPE: nucleic acid
- (C) STRANDEDNESS: single
- (D) TOPOLOGY: linear

- 65 -

(ii) MOLECULE TYPE: cDNA

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:6:

GAATTCTCTA GATCATCACG GGGTTGCAG CAGCA

35

(2) INFORMATION FOR SEQ ID NO:7:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 13 base pairs
- (B) TYPE: nucleic acid
- (C) STRANDEDNESS: single
- (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: cDNA

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:7:

AGCTTAGATC TCC

13

(2) INFORMATION FOR SEQ ID NO:8:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 13 base pairs
- (B) TYPE: nucleic acid
- (C) STRANDEDNESS: single
- (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: cDNA

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:8:

AATTGGAGAT CTA

13

(2) INFORMATION FOR SEQ ID NO:9:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 39 base pairs
- (B) TYPE: nucleic acid
- (C) STRANDEDNESS: single
- (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: cDNA

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:9:

AATTCCAGAC GCTGTCCCCG GAGGGATCCG GCAACTGAG

39

(2) INFORMATION FOR SEQ ID NO:10:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 39 base pairs
- (B) TYPE: nucleic acid
- (C) STRANDEDNESS: single
- (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: cDNA

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:10:

TCGACTCAGT TGCCGGATCC CTCCGGGGAC AGCGTCTGG

39

(2) INFORMATION FOR SEQ ID NO:11:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 1480 base pairs
- (B) TYPE: nucleic acid
- (C) STRANDEDNESS: single
- (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: cDNA

(ix) FEATURE:

- (A) NAME/KEY: CDS
- (B) LOCATION: 74..689

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:11:

GCGGAGAAAG CCAGTGGGAA CCCAGACCCA TAGGAGACCC GCGTCCCCGC TCGGCCTGGC

60

CAGGCCCGC GCT ATG GAG TTC CTC TGG GCC CCT CTC TTG GGT CTG TGC
Met Glu Phe Leu Trp Ala Pro Leu Leu Gly Leu Cys
1 5 10

109

TGC AGT CTG GCC GCT GAT CGC CAC ACC GTC TTC TGG AAC AGT TCA
Cys Ser Leu Ala Ala Asp Arg His Thr Val Phe Trp Asn Ser Ser
15 20 25

157

AAT CCC AAG TTC CGG AAT GAG GAC TAC ACC ATA CAT GTG CAG CTG AAT
Asn Pro Lys Phe Arg Asn Glu Asp Tyr Thr Ile His Val Gln Leu Asn
30 35 40

205

GAC TAC GTG GAC ATC ATC TGT CCG CAC TAT GAA GAT CAC TCT GTG GCA
Asp Tyr Val Asp Ile Ile Cys Pro His Tyr Glu Asp His Ser Val Ala
45 50 55 60

253

GAC GCT GCC ATG GAG CAG TAC ATA CTG TAC CTG GTG GAG CAT GAG GAG Asp Ala Ala Met Glu Gln Tyr Ile Leu Tyr Leu Val Glu His Glu Glu 65 70 75	301
TAC CAG CTG TGC CAG CCC CAG TCC AAG GAC CAA GTC CGC TGG CAG TGC Tyr Gln Leu Cys Gln Pro Gln Ser Lys Asp Gln Val Arg Trp Gln Cys 80 85 90	349
AAC CGG CCC AGT GCC AAG CAT GGC CCG GAG AAG CTG TCT GAG AAG TTC Asn Arg Pro Ser Ala Lys His Gly Pro Glu Lys Leu Ser Glu Lys Phe 95 100 105	397
CAG CGC TTC ACA CCT TTC ACC CTG GGC AAG GAG TTC AAA GAA GGA CAC Gln Arg Phe Thr Pro Phe Thr Leu Gly Lys Glu Phe Lys Glu Gly His 110 115 120	445
AGC TAC TAC TAC ATC TCC AAA CCC ATC CAC CAG CAT GAA GAC CGC TGC Ser Tyr Tyr Tyr Ile Ser Lys Pro Ile His Gln His Glu Asp Arg Cys 125 130 135 140	493
TTG AGG TTG AAG GTG ACT GTC AGT GGC AAA ATC ACT CAC AGT CCT CAG Leu Arg Leu Lys Val Thr Val Ser Gly Lys Ile Thr His Ser Pro Gln 145 150 155	541
GCC CAT GTC AAT CCA CAG GAG AAG AGA CTT GCA GCA GAT GAC CCA GAG Ala His Val Asn Pro Gln Glu Lys Arg Leu Ala Ala Asp Asp Pro Glu 160 165 170	589
GTG CGG GTT CTA CAT AGC ATC GGT CAC AGT GCT GCC CCA CGC CTC TTC Val Arg Val Leu His Ser Ile Gly His Ser Ala Ala Pro Arg Leu Phe 175 180 185	637
CCA CTT GCC TGG ACT GTG CTG CTC CTT CCA CTT CTG CTG CTG CAA ACC Pro Leu Ala Trp Thr Val Leu Leu Leu Pro Leu Leu Leu Gln Thr 190 195 200	685
CCG T GAAGGTGTAT GCCACACCTG GCCTTAAAGA GGGACAGGCT GAAGAGAGGG Pro 205	739
ACAGGCACTC CAAACCTGTC TTGGGGCCAC TTTCAGAGCC CCCAGCCCTG GGAACCACTC	799
CCACCACAGG CATAAGCTAT CACCTAGCAG CCTCAAAACG GGTCAGTATT AAGGTTTCA	859
ACCGGAAGGA GGCCAACCAAG CCCGACAGTG CCATCCCCAC CTTCACCTCG GAGGGACGGA	919
GAAAGAAGTG GAGACAGTCC TTTCCCACCA TTCTGCCTT TAAGCCAAAG AAACAAGCTG	979
TGCAGGCATG GTCCCTTAAG GCACAGTGGG AGCTGAGCTG GAAGGGGCCA CGTGGATGGG	1039
CAAAGCTTGT CAAAGATGCC CCCTCCAGGA GAGAGCCAGG ATGCCAGAT GAACTGACTG	1099
AAGGAAAAGC AAGAAACAGT TTCTTGCTTG GAAGCCAGGT ACAGGAGAGG CAGCATGCTT	1159
GGGCTGACCC AGCATCTCCC AGCAAGACCT CATCTGTGGA GCTGCCACAG AGAAGTTGT	1219
AGCCAGGTAC TGCATTCTCT CCCATCCTGG GGCAGCACTC CCCAGAGCTG TGCCAGCAGG	1279

GGGGCTGTGC CAACCTGTTG	1339
TTAGAGTGTAA GCTGTAAGGG CAGTGCCCAT GTGTACATTC	
TGCCTAGAGT GTAGCCTAAA GGGCAGGGCC CACGTGTATA GTATCTGTAT ATAAGTTGCT	1399
GTGTGTCTGT CCTGATTCT ACAACTGGAG TTTTTTATA CAATGTTCTT TGTCTAAAA	1459
TAAAGCAATG TGTTTTTCG G	1480

(2) INFORMATION FOR SEQ ID NO:12:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 205 amino acids
- (B) TYPE: amino acid
- (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: protein

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:12:

Met Glu Phe Leu Trp Ala Pro Leu Leu Gly Leu Cys Cys Ser Leu Ala	
1 5 10 15	
Ala Ala Asp Arg His Thr Val Phe Trp Asn Ser Ser Asn Pro Lys Phe	
20 25 30	
Arg Asn Glu Asp Tyr Thr Ile His Val Gln Leu Asn Asp Tyr Val Asp	
35 40 45	
Ile Ile Cys Pro His Tyr Glu Asp His Ser Val Ala Asp Ala Ala Met	
50 55 60	
Glu Gln Tyr Ile Leu Tyr Leu Val Glu His Glu Glu Tyr Gln Leu Cys	
65 70 75 80	
Gln Pro Gln Ser Lys Asp Gln Val Arg Trp Gln Cys Asn Arg Pro Ser	
85 90 95	
Ala Lys His Gly Pro Glu Lys Leu Ser Glu Lys Phe Gln Arg Phe Thr	
100 105 110	
Pro Phe Thr Leu Gly Lys Glu Phe Lys Glu Gly His Ser Tyr Tyr Tyr	
115 120 125	
Ile Ser Lys Pro Ile His Gln His Glu Asp Arg Cys Leu Arg Leu Lys	
130 135 140	
Val Thr Val Ser Gly Lys Ile Thr His Ser Pro Gln Ala His Val Asn	
145 150 155 160	
Pro Gln Glu Lys Arg Leu Ala Ala Asp Asp Pro Glu Val Arg Val Leu	
165 170 175	
His Ser Ile Gly His Ser Ala Ala Pro Arg Leu Phe Pro Leu Ala Trp	
180 185 190	
Thr Val Leu Leu Leu Pro Leu Leu Leu Gln Thr Pro	
195 200 205	

- 69 -

(2) INFORMATION FOR SEQ ID NO:13:

(i) SEQUENCE CHARACTERISTICS:
(A) LENGTH: 5 amino acids
(B) TYPE: amino acid
(C) STRANDEDNESS: single
(D) TOPOLOGY: linear

(ii) MOLECULE TYPE: protein

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:13:

Lys Arg Leu Ala Ala
1 5

(2) INFORMATION FOR SEQ ID NO:14:

(i) SEQUENCE CHARACTERISTICS:
(A) LENGTH: 23 amino acids
(B) TYPE: amino acid
(C) STRANDEDNESS: single
(D) TOPOLOGY: linear

(ii) MOLECULE TYPE: protein

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:14:

Asp Arg His Thr Val Phe Asp Asn Ser Ser Asn Pro Lys Phe Arg Asn
1 5 10 15

Glu Asp Tyr Ile His Val Gln
20

(2) INFORMATION FOR SEQ ID NO:15:

(i) SEQUENCE CHARACTERISTICS:
(A) LENGTH: 39 base pairs
(B) TYPE: nucleic acid
(C) STRANDEDNESS: single
(D) TOPOLOGY: linear

(ii) MOLECULE TYPE: cDNA

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:15:

GAATTCTCTA GATTCATGG AAGGAGCAGC ACAGTCCAG

- 70 -

(2) INFORMATION FOR SEQ ID NO:16:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 39 base pairs
- (B) TYPE: nucleic acid
- (C) STRANDEDNESS: single
- (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: cDNA

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:16:

GAATTCTCTA GATTATCATG GGAAGAGGCG TGCGGCAGC

39

(2) INFORMATION FOR SEQ ID NO:17:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 41 base pairs
- (B) TYPE: nucleic acid
- (C) STRANDEDNESS: single
- (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: cDNA

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:17:

GAATTCTCTA GATTATCATG GGGCAGCACT GTGACCGATG C

41

WHAT IS CLAIMED IS:

1. A purified and isolated polypeptide specifically binding the eck receptor and having
5 substantially the same amino acid sequence as shown in SEQ. ID. NO. 1.
2. The polypeptide of Claim 1 which induces phosphorylation of the eck receptor.
10
3. The polypeptide of Claim 1 having an amino acid sequence as shown in SEQ. ID. NO. 1 terminating at position 150 or having substantially the same amino acid sequence as shown in SEQ. ID. NO. 1 terminating at
15 position 150.
4. The polypeptide of Claim 3 wherein the amino acid sequence is from position +1 to 150 as shown in SEQ. ID. NO. 1.
20
5. The polypeptide according to Claim 1 having a methionine residue at position -1.
6. The polypeptide according to Claim 5
25 selected from the group consisting of [Met⁻¹] EBP¹⁻¹⁵⁰ and [Met⁻¹] EBP¹⁻¹⁵⁹.
7. The polypeptide according to Claim 1
30 selected from the group consisting of EBP¹⁻¹⁶⁷, EBP¹⁻¹⁷¹ and EBP¹⁻¹⁸⁰.
8. The polypeptide of Claim 1 which is characterized by being the product of prokaryotic or eucaryotic expression of an exogenous DNA sequence.
35

9. The polypeptide of Claim 8 which is the product of CHO cell expression.

10. The polypeptide of Claim 8 wherein the 5 exogenous sequence is a cDNA sequence.

11. The polypeptide of Claim 8 wherein the exogenous sequence is a genomic DNA sequence.

10 12. The polypeptide of Claim 8 wherein the exogenous sequence is a synthetic DNA sequence.

13. The polypeptide of Claim 8 wherein the 15 exogenous DNA sequences is carried on an autonomously replicating DNA plasmid or viral vector.

14. The polypeptide of Claim 8 which is the product of *E. coli* expression.

20 15. The polypeptide of Claim 8 having an N-terminal methionine residue.

16. A DNA sequence encoding a polypeptide 25 specifically binding the eck receptor, wherein said polypeptide has a methionine residue at position -1 and has substantially the same amino acid sequence as shown in SEQ. ID. NO. 1.

17. A DNA sequence according to Claim 16 30 encoding [Met⁻¹] EBP¹⁻¹⁵⁰ and [Met⁻¹] EBP¹⁻¹⁵⁹.

18. A DNA sequence encoding EBP¹⁻¹⁶⁷, EBP¹⁻¹⁷¹ and EBP¹⁻¹⁸⁰.

35 19. An isolated eck receptor-ligand complex.

20. The receptor-ligand complex according to
Claim 13 wherein the ligand is the polypeptide according
to Claim 1.

5 21. A method for detecting in crude samples a
ligand capable of binding to a receptor comprising the
steps of:

a) immobilizing a purified ligand binding
domain of the receptor;
10 b) contacting the immobilized receptor with
conditioned medium containing the ligand; and
c) monitoring the binding of the ligand to the
immobilized receptor by a surface plasmon resonance
detection system.

15

22. The method of Claim 21 wherein the
receptor is the eck receptor.

20 23. A method of modulating the endogenous
activity of an eck receptor in a mammal comprising
administering to the mammal an effective amount of a
ligand to the eck receptor to modulate the activity of
said receptor.

25 24. The method according to Claim 23 wherein
the ligand is the polypeptide of Claim 1.

30 25. The method according to Claim 23 wherein
the modulation of said eck receptor activity regulates
cellular functions comprising differentiation,
proliferation and metabolism.

35 26. A method for identifying compounds that
modulate the activity of an eck receptor comprising the
steps of:

a) exposing cells exhibiting the receptor to known ligands for a time sufficient to allow formation of receptor-ligand complexes and induce signal transduction;

5 b) determining the extent of activity within the cells; and
c) comparing the measured activity to the activity in cells not exposed to the ligand.

10 27. A method for the treatment of cancer in a patient comprising administering a therapeutically effective amount of an eck receptor ligand.

15 28. A method for the treatment of cancer in a patient comprising administering a therapeutically effective amount of the ligand of Claim 27 wherein said ligand binds to, but does not phosphorylate the eck receptor.

20 29. A method for the treatment of cancer in a patient comprising administering a therapeutically effective amount of an eck soluble receptor.

25 30. A method as in either of Claims 27, 28 or 29 further comprising a therapeutically effective amount of chemotherapy or radiation therapy.

30 31. A method for the treatment of inflammation in a patient comprising administering a therapeutically effective amount of an eck soluble receptor.

35 32. A method for the treatment of inflammation in a patient comprising administering a therapeutically effective amount of an eck receptor

- 75 -

ligand wherein said ligand binds to, but does not phosphorylate the eck receptor.

33. A method for the treatment of a wound in
5 a mammal comprising administering a therapeutically effective amount of an eck receptor ligand.

34. A method for increasing hematopoiesis in
a mammal comprising administering a therapeutically
10 effective amount of an eck receptor ligand.

35. The method according to Claim 34 wherein the ligand is the polypeptide of Claim 1.

15 36. A method for stimulating proliferation of colon cells comprising administering a therapeutically effective amount of an eck receptor ligand.

20 37. The method according to Claim 36 which is used in conjunction with cancer therapy.

38. The method according to Claim 36 wherein the ligand is the polypeptide of Claim 1.

25 39. A method for stimulating proliferation of hepatocytes comprising administering a therapeutically effective amount of an eck receptor ligand.

30 40. A method according to Claim 39 wherein the ligand is the polypeptide of Claim 1.

41. A method for treating neurological disorders comprising administering a therapeutically effective amount of an eck receptor ligand.

42. The method according to Claim 41 wherein the disorder is selected from the group consisting of amyotrophic lateral sclerosis, spinal cord injury, Alzheimer's disease, Parkinson's disease, ischemia, 5 Huntington's disease, multiple sclerosis, nerve trauma and peripheral neuropathies.

43. The method according to Claim 41 further compromising administering a therapeutically effective 10 amount of ciliary neurotrophic factor, brain derived neurotrophic factor, glial derived neurotrophic factor, nerve growth factor, insulin-like growth factor-1 or neurotrophin-3.

15 44. A pharmaceutical composition comprising a therapeutically effective amount of an eck receptor ligand and a pharmaceutically acceptable diluent, adjuvant or carrier.

20 45. A pharmaceutical composition comprising a therapeutically effective amount of an eck soluble receptor and a pharmaceutically acceptable diluent, adjuvant or carrier.

25 46. A composition comprising the polypeptide of Claim 1 and a detergent.

Molecular Weight
Markers

1 2 3 4 5 6

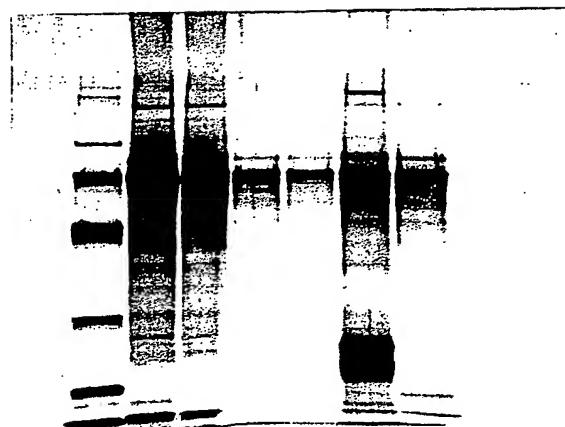


FIG. IA

Molecular Weight
Markers

1 2 3 4 5 6



FIG. IB

Superdex-75
Eck Binding Protein (HCT-8) with BSA as Carrier

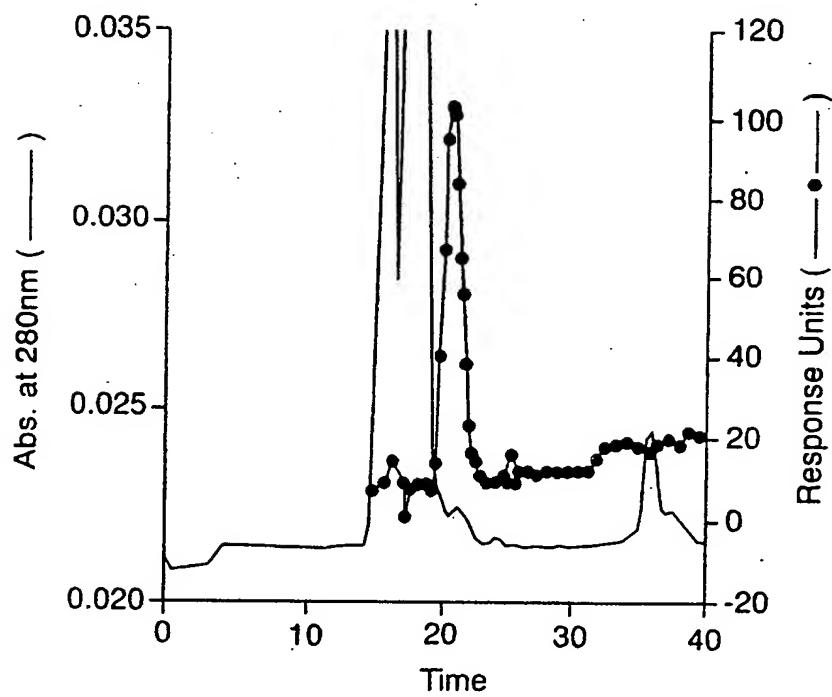


FIG. 2

FIG. 3

Q-SEPHAROSE CHROMATOGRAPHY
OF RECOMBINANT EBP

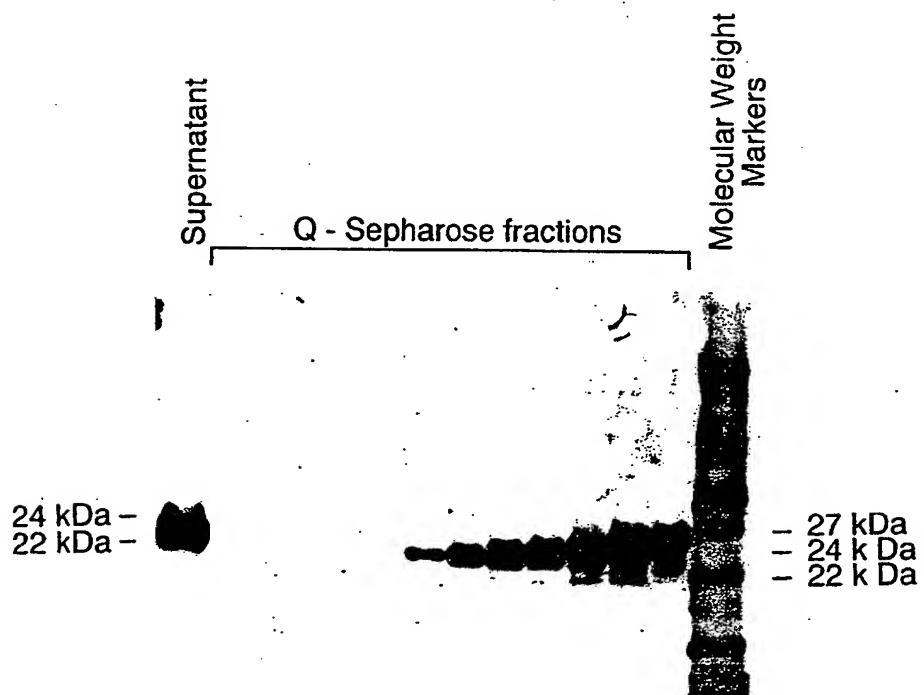


FIG. 4

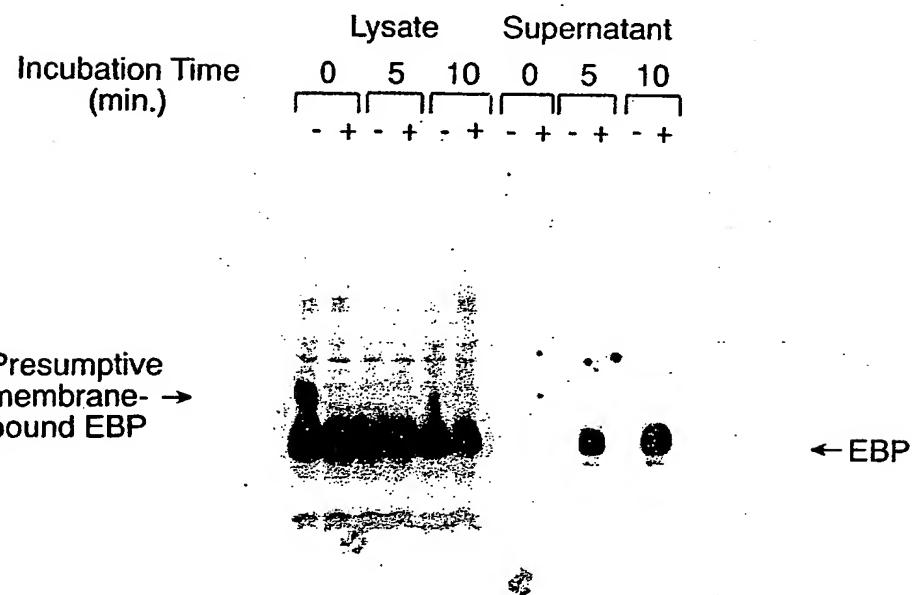
RELEASE OF MEMBRANE-BOUND
RECOMBINANT EBP

FIG. 5

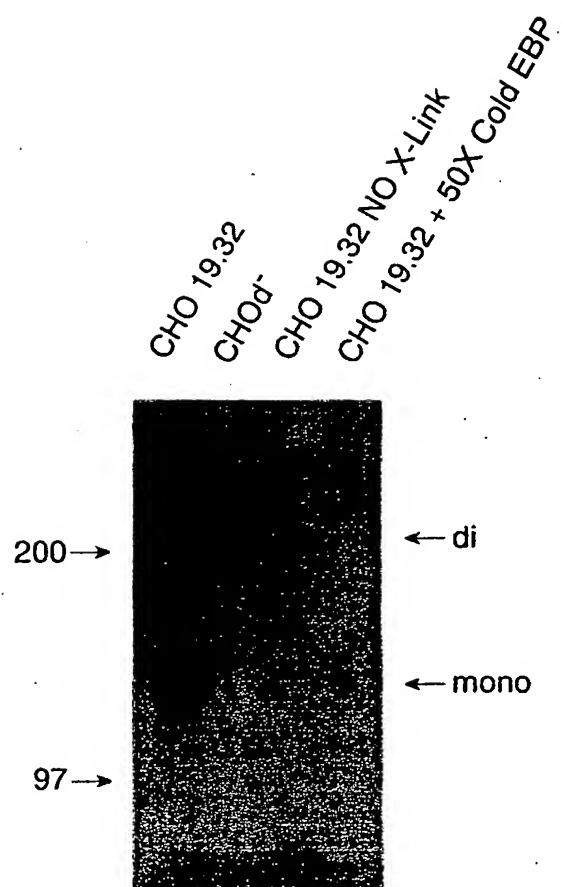
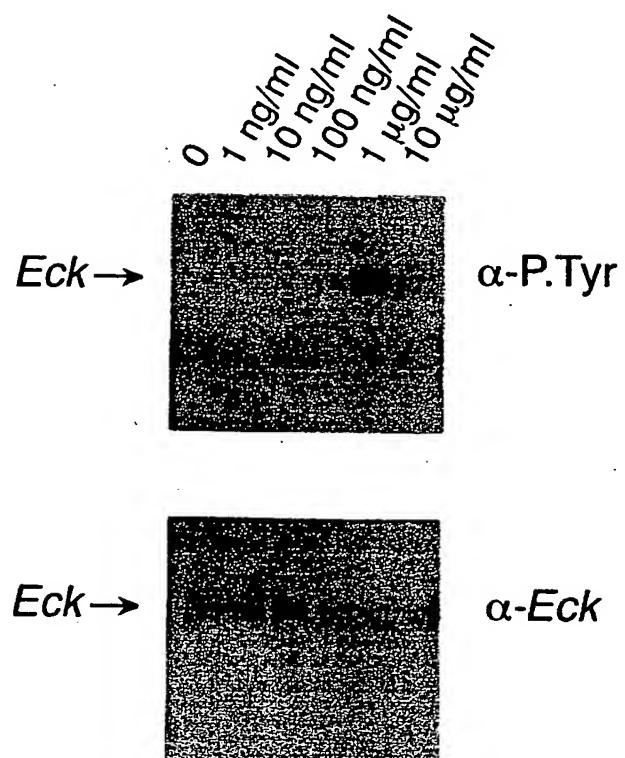
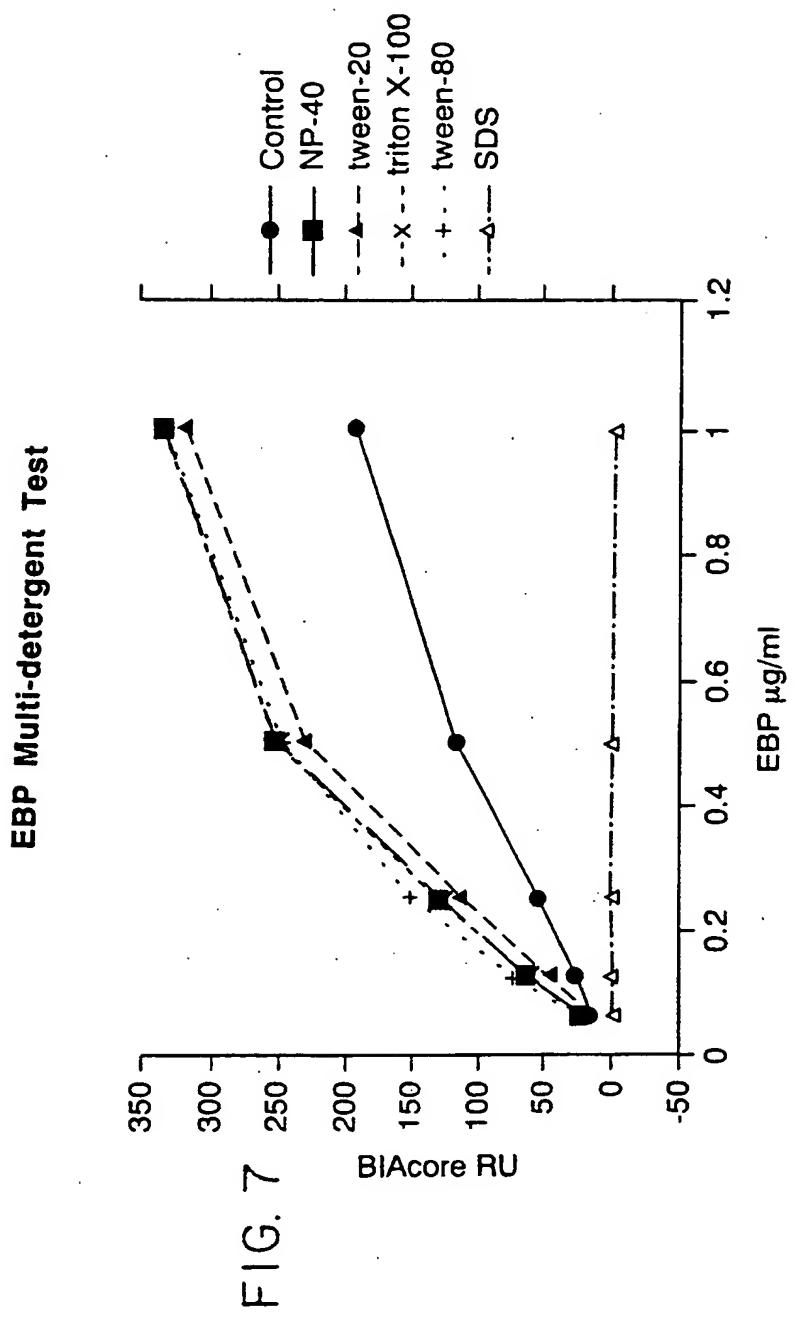


FIG. 6

Eck Receptor Tyrosine Kinase
Activation with rEBP





EFFECTS OF EBP ON MURINE HEMATOPOIESIS

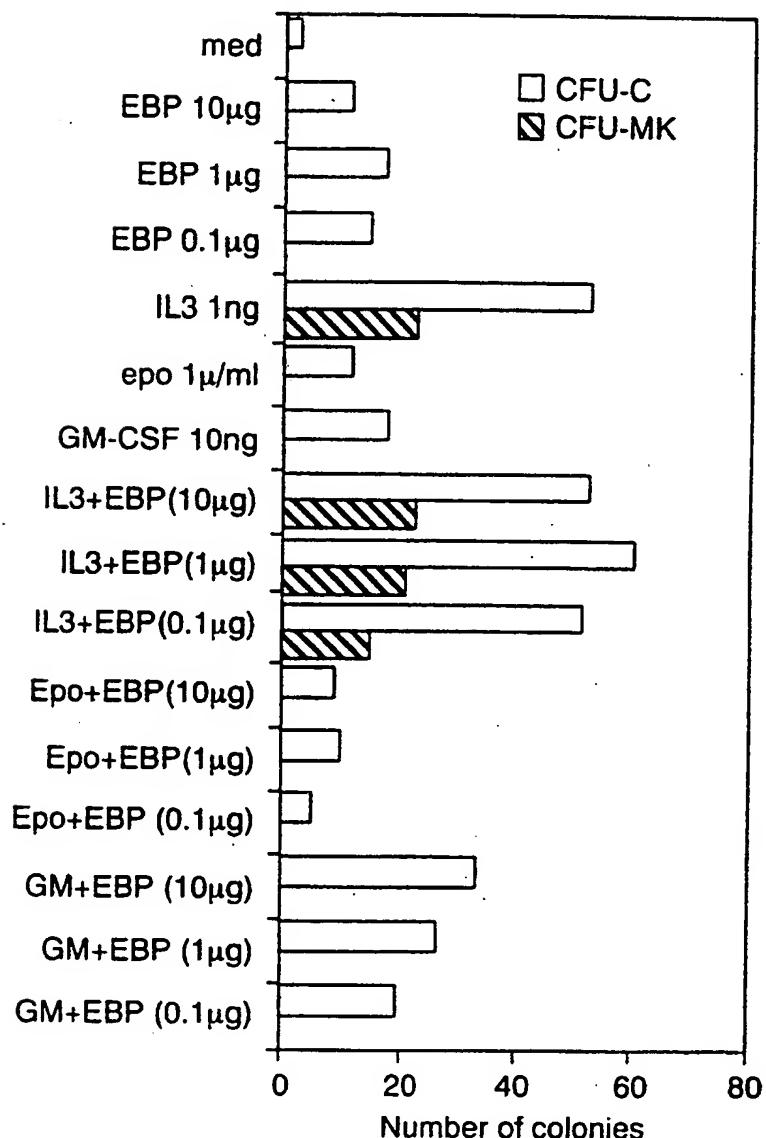


FIG. 8

3H-Thymidine Incorporation In Response To The Addition Of Growth Factors

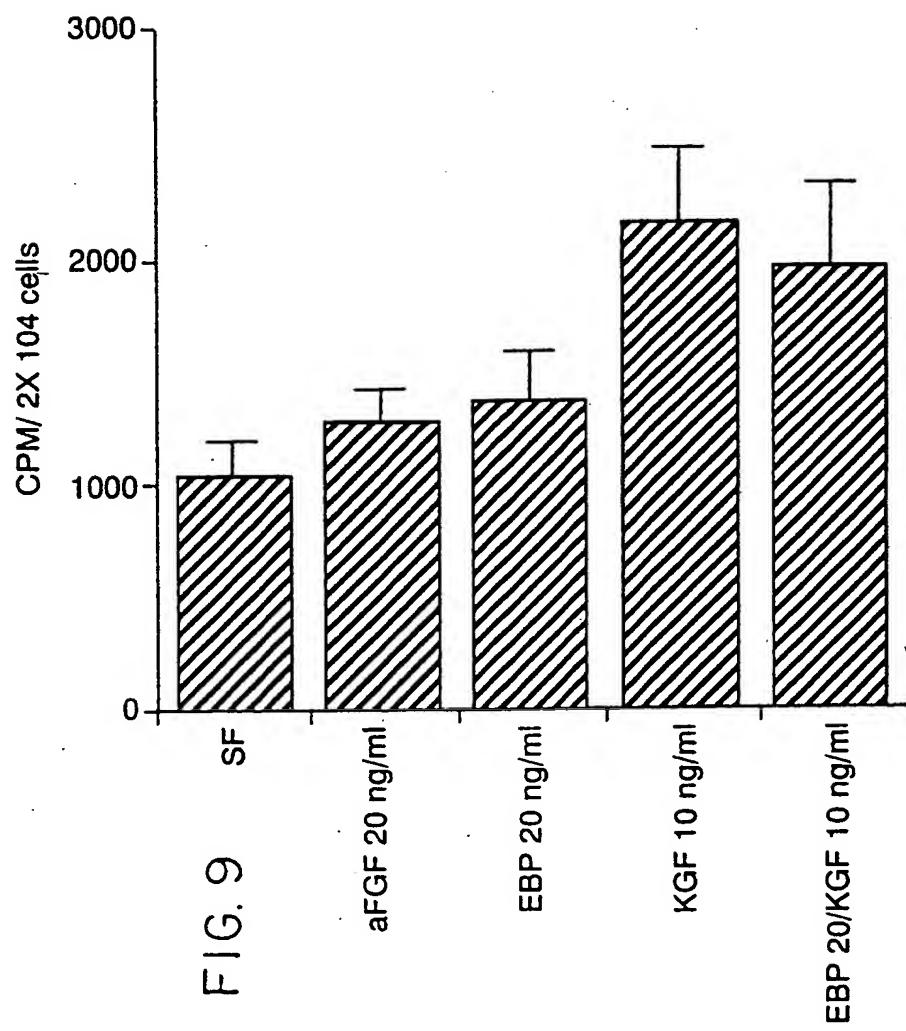
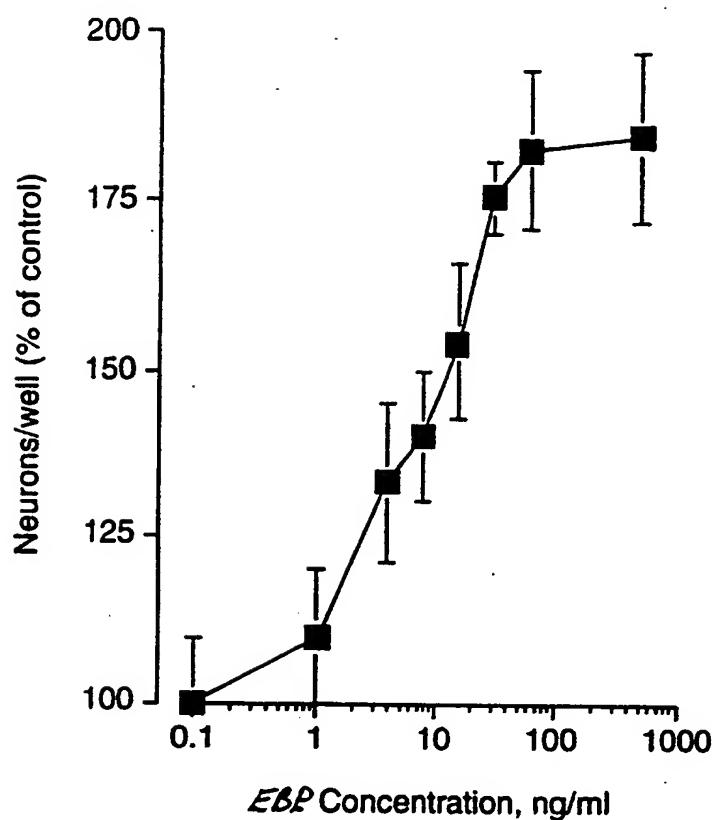


FIG. 10



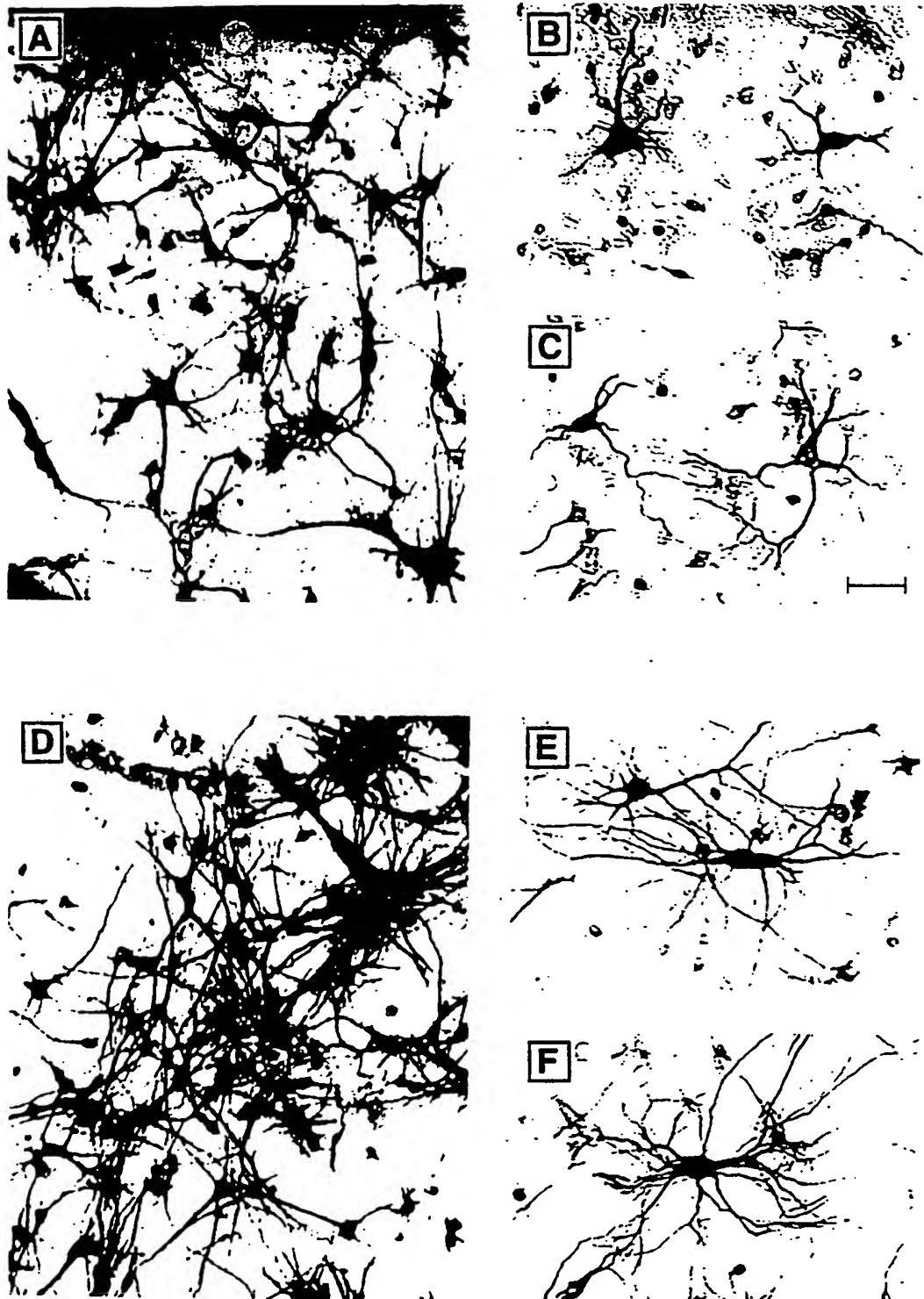


FIG. 11

FIG. 12A

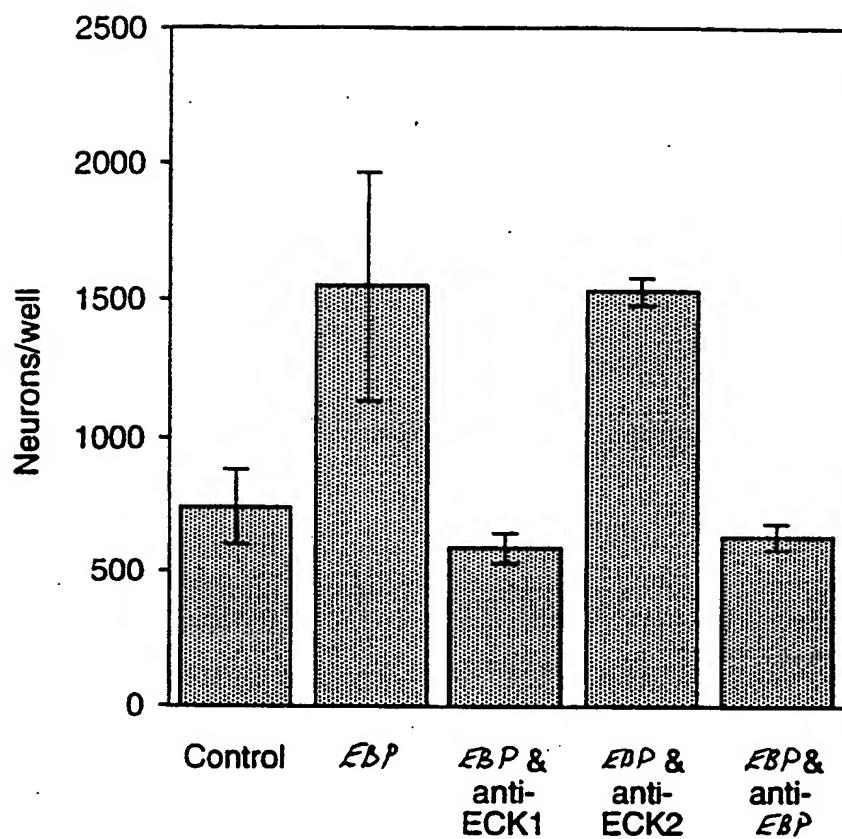
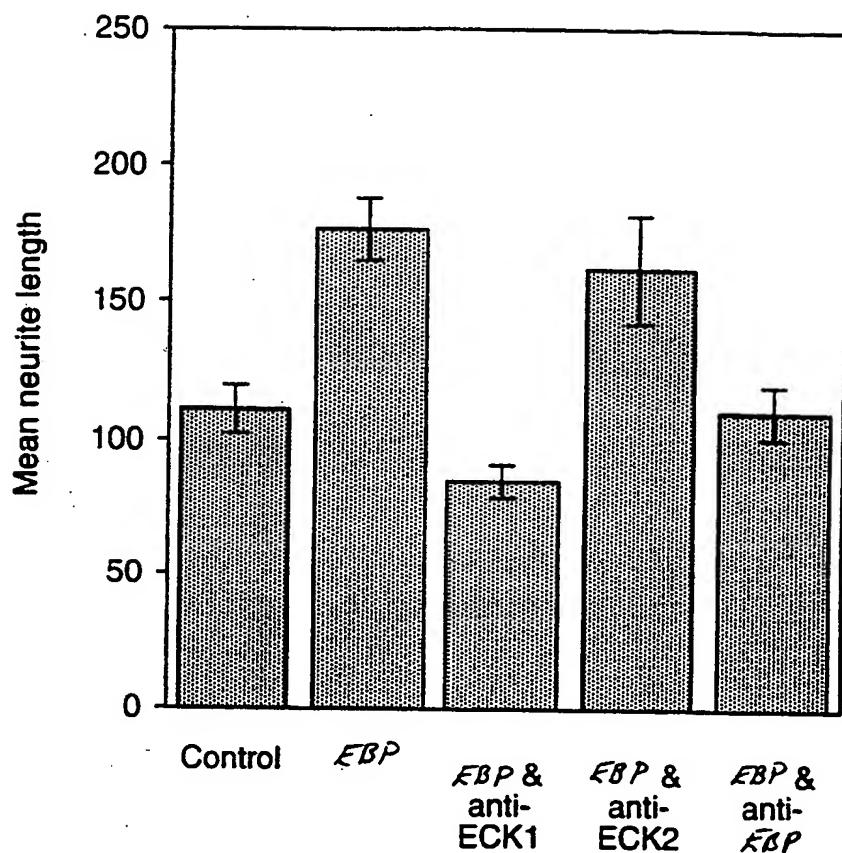


FIG. 12B



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